PROCEEDINGS

SECOND CANADIAN CONFERENCE ON

URBAN INFRASTRUCTURE

DÉLIBÉRATIONS

Du Second Colloque Canadien Sur Les

INFRASTRUCTURES URBAINES

held February 13 and 14, 1989
Edmonton, Alberta

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The Federation
of Canadian
Municipalities

The University
of Alberta

The University
of Toronto

Co-Sponsors

Canadian Society for Civil Engineering
Canadian Water and Wastewater Association
Western Canada Water and Wastewater Association

January 1991

92-06334/

Proceedings of the Second Canadian Conference on Urban Infrastructure.

Produced by:

Sodanell Canada Inc.
P. O. Box 8280
Station F
Edmonton, Alberta
Canada T6H 4P1

Distributed by:

Federation of Canadain Municipalities
24 Clarence Street
Ottawa, Ontario
Canada K1N 5P3

ISBN 0-921905-01-7

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Published by

Sodanell Canada Inc.
Edmonton, Alberta

Printed by
Printing Services
University of Alberta
Edmonton

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PREFACE

The Second Canadian Conference on Urban Infrastructure was designed to build on the success of the First Conference held in Toronto in 1987. The partnership between the Federation of Canadian Municipalities, the University of Alberta and the University of Toronto was maintain to ensure a variety of concerns and interests were represented.

The Conference brought together political, financial and technical decision makers officials of municipal, provincial, territorial and federal governments, consulting engineers, contractors and educators - all with an important role in the struggle to maintain the environmental quality and quality of life in Canadian cities.

The detailed topics of financing, management and engineering for renewal formed the backbone of Conference under the umbrella of national and prairie province needs. Throughout the conference and these proceeding it is evident that urban area planning must recognize the eventual need for renewal of all built components of our urban environment.

The format of the proceedings follow the actual program of the conference.

Daniel W. Smith

ACKNOWLEDGEMENT

The effort of all those that prepared manuscripts and made presentations must be recognized for they made the conference a success. In addition the transfer of the manuscripts to a suitable word processors did not go smoothly and required hundreds of hours of work correcting, reformating and retyping. The efforts of Ms. Linda Z. Schulz and Ms. Jo-Ann Latta are gratefully acknowledged.

In addition, an extra effort was made by Mr. Daniel Tetreault of The Federation of Canadian Municipalities, Ottawa, to co-ordinate some aspects of the conference.
Dr. Gordon J. Smith of the Department of Public Works, City of Edmonton provided a great deal of assistance with local arrangements for the conference. These efforts were greatly appreciated.

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G. B. Cuff, President, Federation of Canadian Municipalities

HEALTH AND SAFETY IMPERATIVE

Gordon Atherley
President and CEO
Canadian Centre for Occupational
Health and Safety

ABSTRACT

Some of the hazards to the health and safety of the public, construction workers and municipal employees resulting from the infrastructure operation, maintenance and construction will be covered.

RÉSUMÉ

Cet exposé présentera quelques-uns des risques pour le public, les travailleurs de la construction et les employés municipaux découlant de l'entretien et de la construction des infrastructures urbaines.

FRAGILE FOUNDATIONS: THE U.S. EXPERIENCE

Nancy S. Rutledge
Former Executive Director
U.S. National Council on Public Works Improvement
Research Associate
Taubman Center for State and Local Government
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ABSTRACT

The U.S. National Council on Public Works Improvement was created to provide a thorough and objective assessment on the state of the nation's infrastructure. The 5-member commission, appointed by the President and the Congress, commissioned and reviewed over 5,000 pages of research over a 2-year period. In its final report, Fragile Foundations, issued in February 1988, the Council concluded that the quality of the infrastructure in the U.S.A. is barely adequate to fulfill current requirements and insufficient to meet the demands of future economic growth and development. The Council recommended a bold and broad-based strategy to reverse this trend, including significant increases in investment and aggressive management, maintenance, and research strategies. The report continues to be the subject of continuing review and comment by the media, Congressional members and staff, and a wide range of public and private interest groups.

RÉSUMÉ

Le "U.S. National Council on Public Works Improvement" a été mis sur pied dans le but de se livrer à une évaluation approfondie et objective de l'état des infrastructures du pays. La commission, constituée de cinq membres nommés par le Président et le Congrès, a reçu le mandat, d'une durée de deux ans, de passer en revue plus de 5 000 pages de recherche documentée. Dans son rapport final, Fragile Foundations, publié en février 1988, le Conseil conclut que la qualité des infrastructures des États-Unis leur permet à peine de satisfaire aux besoins courants, et qu'elles ne pourront donc pas répondre à la croissance et au développement économiques de demain. Le Conseil recommande d'adopter une audacieuse stratégie tentaculaire de manière à renverser la tendance, dont d'importantes augmentations des dépenses d'immobilisations et des techniques dynamiques

de gestion, d'entretien et de recherche. Le rapport fait toujours l'objet d'une revue et d'observations constantes de la part des médias, des membres du Congrès et de son effectif, ainsi que du grant public et de groupes d'intérêts privés.

BACKGROUND OF THE ISSUE IN THE U.S.

The word "infrastructure" emerged like a sudden squall on the American political scene in the early 1980s. Our basic public facilities - transportation, water supply, and waste disposal systems - were reported to be in perilous condition (Joint Economic Committee of the Congress, 1984). By one account (Choate and Walters, 1983), America was said to be "in ruins" and the magnitude of needs was estimated by the Associated General Contractors of America to be in the trillions of dollars.

Almost on cue, the calamitous failure of a major bridge on the Connecticut Turnpike offered grim testimony to the immediacy and seriousness of this alarm. It was a powerful image and fortunately a very rare event. Public horror far exceeded the normal reaction to accidents of similar magnitude. For a moment we could no longer trust the integrity of commonplace things. The jurisdictional, technical, and financial issues related to that accident were far less compelling in the public's mind than the simple fact that government did not do its job properly.

Unfortunately, the image was effective neither in sustaining public interest nor in creating political momentum for change. Congress was starting to peer into the growing abyss of the federal budget deficit. At the same time, the traditional role of the federal government in domestic issues was undergoing a sea-change. The "Reagan Revolution" and public skepticism about the effectiveness and value of federal assistance programs prompted a major retrenchment. The staggering numbers associated with repairing our nation's infrastructure were simply neither credible nor compatible with the nation's mood at that time.

Yet the physical evidence of infrastructure deterioration was difficult to deny. Various legislative proposals were introduced but foundered for lack of enthusiasm and support. Finally, in the time-honored tradition of American politics (and elsewhere), Congress established a blue-ribbon commission in late 1984 to study the issue. Unlike earlier studies, the emphasis this time was not on compiling the definitive "wish-list" but rather to assess the condition of the nation's public works system and its capacity to sustain our present and future economy.

MAKE-UP OF THE COUNCIL

The National Council on Public Works Improvement was composed of five members, three appointed by the President and the two by the Congress. Its enabling legislation also set up a 12-member advisory group, chaired by the U.S. Secretary of the Army, to assist the Council. The advisory group also included the heads of five other key federal agencies and the presidents or chairmen of the major state and local government associations.

The members of the Council did not come together as advocates or "true believers" about the nature and the magnitude of the nation's infrastructure problems, much less the appropriate solutions. They reflected a very broad spectrum of political perspectives and professional expertise with little common ground at the outset. Two of the members came from the financial community, one was a newspaper executive, another a local elected official, and the fifth was the appointed head of a state transportation department and a registered engineer .

THE RESEARCH PROCESS

Over 2 years we conducted an exhaustive research effort, along with numerous public hearings and other public outreach programs. All of our research was field-tested by practitioners, elected officials, business leaders, and technical experts from all over the country. The American Public Works Association, the National League of Cities, the American Planning Association, the American Society of Civil Engineers, and numerous other organizations played prominent roles in providing the Council with research as well as formal and informal review of virtually all of our in-house and commissioned work in progress.

In short, we lived in a glass house for 2 years. And no stone was neither left unturned nor unthrown.

The Council's work created an immense reservoir of information and original analyses on the complex and poorly understood subject of infrastructure. However, I believe that the research process was at least as important as the results. The members of the Council, its staff, and the thousands of people who participated actually learned something. The staff and I talked to dozens of people everyday from all over the country, and indeed the world, who called to ask questions and to get information and encouragement.

In the end, this work also served as the foundation for an extraordinary consensus among the five members of the Council, the advisory group, and a wide range of the technical, professional and trade groups concerned about the infrastructure issue. That consensus was hard-won and is embodied in the Council's final report, Fragile Foundations: A Report on America's Public Works, submitted to the President and Congress on February 24, 1988.

RESEARCH FINDINGS AND CONCLUSIONS

Fragile Foundations offers a sobering appraisal of the condition and capacity of the basic facilities on which we depend every day. America's infrastructure is not in ruins, but it is wearing out and rusting out at an alarming rate. It is also providing less service at a point when the nation's continuing economic growth and environmental consciousness demand more.

It is noteworthy, I think, that a group as diverse and often contentious as the Council was able to collectively issue a statement that read:

> "...the quality of America's infrastructure is barely adequate to fulfill current requirements and insufficient to meet the demands of future economic growth and development."

To this assessment they added a warning that

> "...unless we dramatically enhance the capacity and performance of the nations's public works, our own generation will forfeit its place in the American tradition of commitment to the future. Without such an effort, our legacy will be modest at best. At worst, we will default on our obligation to the future and succeeding generations will have to compensate for our failures."

The Report Card on Public Works

To make this message powerful and understandable in this age of 30-second sound bites, we distilled our thousands of pages of research into a grade school report card. Overall, the U.S. public works gets a middling "C". The grades ranged from a high of "B" for water resources (ports, canals, dams, and flood control facilities) and "B-" for water supply and airports and airways to a low of "D" for hazardous waste disposal (I think many would now say that an "F" is more fitting). The rest - highways, mass transit, solid waste disposal, and wastewater treatment facilities - all clustered around "C-" and "C+."

This was not a report card to make a parent proud or to assure a great and glorious future for their issue. While these are obviously not quantified assessments, they have held up remarkably well to critical reviews, some of them by the leading experts in each category.

Economic Implications

Even more troubling than analyses of specific categories of infrastructure was the evidence of a pattern of public disinvestment in the U.S.A. Overall private capital and public spending and public works investments are, relative to the GNP, on a slippery slide. There is no absolute benchmark for the correct level of investment, but we have learned that private capital spending is less efficient when it has to compensate continually for a failing, inadequate, or unreliable infrastructure system.

As you perceive not only the same downward trend in a variety of economic indicators relative to infrastructure investment but actually also see increasing physical evidence of infrastructure deterioration and congestion, you do not have to be a brilliant economist to see that the U.S.A. has a potentially serious problem. This assertion has been corroborated in a recent study by the Federal Reserve Bank of Chicago.

It is no longer just the aggravation of potholes and crowded airports, or the threat of bridge failures: the nation's productivity and ability to compete in the long-term are increasingly at stake.

Message to Decision-Makers

The message from the Council to policy-makers at the federal, state, and local level is simple: it is short-sighted to talk about jobs and growth unless you intend to make public works a priority. That priority must be reflected in the budgets you pass and the funding proposals you support.

Not Just a Matter or Money

We did not argue in favour of simply throwing money at the problem. In order to convince the American public to invest rather than to spend more, we have to do a better job of planning and managing the nation's public works. We need to establish more clearly who is accountable at each level of government for making and following through, crucial decisions. We need to make federal and state mandates more flexible to allow cost-effective methods of compliance. We need to promote stronger incentives and support for proper maintenance, and we need to accelerate technological innovation and the development of the human factor - the skills and commitment of the people who are directly responsible for public works. Finally we need a rational capital budgeting process at all levels of government.

Who Pays the Bill?

The keystone of our strategy to finance public works is the benefit principle: those who benefit from public works should pay for them. This is not a dogmatic idea. There are situations, such as low-income residents or hard-to-serve communities, in which various types of assistance may be necessary. But in general, user fees provide more predictable revenues, encourage better maintenance and more timely rehabilitation or replacement, and support new development more aligned with actual rates of growth.

Role and Responsibilities of Federal Government

While the Council endorsed a doubling of real capital spending for public works by the end of this century, it did not propose any gigantic new federal spending programs. Nevertheless, it strongly supported an expanded federal role in terms of leadership, research and development, and capital formation. Congress must also pay close attention to the impact that federal laws and requirements have on the ability of state and local governments to finance infrastructure.

State Government and the Private Sector

State government for its part must invest more in sustaining local infrastructure, particularly in small cities and farm communities that have been hard-hit by economic downturns. States should also closely examine the impact of their tax limitations on local fiscal capacity. We cannot insist that city and county officials pay more if they do not have the basic revenue and financing tools to do the job. Finally, the private sector, especially the development community, should pay its fair share of the up-front cost of new infrastructure. We have learned too many times that the infrastructure "catch-up" game being played in many of our cities right now is horrendously expensive and inefficient.

AFTERMATH OF COUNCIL'S WORK

I am pleased that the Council's works is still getting a remarkable amount of press attention and public citation nearly a year after its final release. Normally the shelf-life of the standard "blue-ribbon" federal report is measured in minutes, not months. In fact, coverage is much more thoughtful than the simple re-hash of our press release and report card when the final report was issued a year ago.

It is not especially gratifying to witness some of our dire predictions becoming real. Instead of the rare episode of bridge failure, the infrastructure issue is now associated with daily traffic jams, airport turmoil, closed beaches, overloaded garbage dumps, sewer hook-up bans, and water restrictions. These are events that in one form or another touch nearly every U.S. citizen every single day.

While there is a certain intensity of public interest in the issue right now, we do not have a clear set of policy alternatives. Most of the media and infrastructure advocates are focused almost exclusively on the question of finance - not what we spend it on or the level of service we get for it. I believe that we are still looking for the tooth fairy.

ROOT CAUSES OF INFRASTRUCTURE DECLINE

Despite the extensive work of the Council and numerous other groups, we have only begun to understand the causes of infrastructure deterioration and declining service. Some of the predominant causes are:

- the lack of systematic diagnostic and maintenance systems;
- inadequate capital planning and land-use controls;
- our propensity to create garbage and wastewater, and to drive more cars than in the past;
- the slow pace of infrastructure innovation and productivity improvement; and
- conflicting agendas among various public agencies, political jurisdictions and the private sector.

Public works policy in the U.S.A. is purely ad hoc. Millions of decisions are made everyday in government and businesses and by ordinary citizens with profound implications for infrastructure capacity and performance without any recognition or acknowledgement of the systems and the individuals which provide the service.

That great "Policy Primeval Soup" (Kingdon, 1984) has not yet yielded any dominant ideas that address this problem or meet the basic tests of technical and budgetary feasibility, alignment with national mood, and enthusiastic political support. Natural selection in politics, as in nature, takes time.

CRITICAL ROLE OF THE PUBLIC WORKS PROFESSION

The infrastructure issue still manages to propel repeated Congressional hearings, study commissions, books, seminars, newsletters, consulting firms, and a whole mob of people, like myself, who never do anything truly practical such as build bridges, maintain sewer pipes, or invent new forms of solid waste disposal.

What troubles me is that the "infrastructure mob" rarely includes or consults with anyone in the traditional public works profession. Clearly most public works professionals have more pressing things to do than sit in tedious hearings and meetings or pound the corridors of the Congress or state house. I believe, however, that the profession needs a stronger presence and voice in the political and policy-making process at both the state and national level.

All of us so-called "infrastructure experts", politicians, and citizens need to understand public works better from the bottom up. The real experts need to have greater impact on critical investment and resource allocation decisions. And most especially, they need to help us create a clearer and more compelling vision of what our nation's public works infrastructure should be.

CONCLUSION

Infrastructure is a compelling issue for me because it resonates across a broad spectrum of important values. These values help to give the issue an emotional core that I care strongly about.

Infrastructure is a vital element of community: the city or town, the neighborhood, or the land where we live and which we call home. The physical characteristics of infrastructure help to define communities and link them together. How these places look and feel, how safe and clean they actually are, the quality of the environment in and around our communities - all rest heavily on infrastructure placement and design and our stewardship of its various structures.

REMARKS BY PRESIDENT GEORGE CUFF

FEBRUARY 13, 1989

George B. Cuff
Mayor, City of Spruce Grove
President
Federation of Canadian Municipalities (FCM)

ABSTRACT

The FCM program to solve the infrastructure problem will be highlighted. The Federation's commitment to principles embodied in the infrastructure renewal proposals will be discussed. These principles are the need for:

- access to clean water by all Canadians;
- adequate sewage disposal systems which protect our environment;
- safe roads and bridges;
- equity in an infrastructure funding program so that all regions of this country will be assured equal access to a shared funding program;
- an intergovernmental cost-shared infrastructure program recognizing the need for all orders of government to become involved; and
- promoting all three orders of government as equal participants in the funding program.

RÉSUMÉ

Nous traçons les grandes lignes du programme que la FCM a établi dans le but de régler le problème des infrastructures, en plus de signaler l'engagement de la Fédération à l'égard des principes qui sous-tendent les propositions de renouvellement des infrastructures. Ces principes expriment les nécessités suivantes :

- de l'eau potable filtrée pour tous les Canadiens;
- un réseau adéquat d'épuration des eaux usées axé sur la protection de l'environnement;

- des ponts et chaussées sûrs;
- une répartition équitable du financement des infrastructures pour faire en sorte que toutes les régions du pays jouissent de la même accessibilité au programme de financement partagé;
- un programme intergouvernemental d'infrastructure à frais partagés reconnaissant la participation requise de tous les paliers de gouvernement; et
- la mise en valeur de la participation égale des trois paliers de gouvernement au programme de financement.

FCM'S COMMITMENT

The Federation of Canadian Municipalities (FCM) has been hard at work on the issue of municipal infrastructure for 6 years. It has been a long and difficult 6 years. We have invested a great deal of money and spent much energy. We have often rallied the efforts of our members in support of our goals, and have thus put a large stake in a positive outcome.

Our own credibility is on the line. But on no other issue has there been greater unanimity among municipal leaders. Why? Because as local officials we are, more than anyone else, aware of the severity of the problem and of its long-term implications for the health and well-being not only of Canadians but also of the Canadian economy. My remarks today underline our unequivocal, unflagging, and untrammelled commitment on this issue. We are in the discussion for keeps. However long it takes, however much it costs: we intend to prevail.

OUR GOAL

In broad terms, our goal is simple. We seek a higher level of intergovernmental cooperation on the matter of municipal infrastructure renewal and expansion. Canada's provincial and territorial municipal associations communicated this position to their respective governments. FCM's responsibility has been to convey this goal to the Government of Canada.

WHO IS ON SIDE

Collectively our communications efforts have achieved notable results. The federal New Democratic Party confirmed its support early on. The Liberal Party of Canada attempted to make infrastructure a key issue in the 1988 election. In a speech at the Union of British Columbia Municipalities annual conference last September, the Right Honourable John Turner affirmed his party's commitment.

The provinces also, reacting to recommendations from the provincial and territorial associations, have reiterated their support. Following a recommendation from Canada's ministers of municipal affairs, a communiqué was issued at the 29th Annual Premiers Conference in Saskatoon last August stating the following:

> "The Premiers agreed that the continued competitiveness of the Canadian economy will depend to a significant degree on the maintenance and improvement of vital local infrastructure. A healthy economy as well as healthy and livable cities, towns, and villages depend on having adequate transportation networks, water supplies, and sewers."

The Premiers called on the federal government to support the provinces in maintaining the municipal infrastructure to strengthen regional and local economies and to provide a clean and safe environment.

THE SOFTENING FEDERAL POSITION

I can report that the attitude of the Government of Canada has moved away from its initial hostile reaction to a more open and accommodating position. I sincerely thank the federal Department of the Environment and its new Minister, Lucien Bouchard, for supporting this conference. We take this support as a signal that the position adopted earlier has softened in response to political realities, public attitudes, provincial support, and perhaps, reason. We also acknowledge the Prime Minister's agreement that the issue of municipal infrastructure will be discussed at the forthcoming First Ministers' meeting. The log jam may not have broken, but there is movement.

OTTAWA IS IN, WHETHER IT SAYS SO OR NOT

Even when the federal government was verbally stonewalling the issue, its actions belied its statements. An examination of federal expenditures from 1985 to 1987 reflects a recognition of the importance of local infrastructure needs. For example, during the mid-1980s, Ottawa participated as a major contributor to the enhancement of Regina's drinking water supply system. More recently, it agreed to be a participant in a proposal to install sewage treatment facilities in Halifax through cost-sharing with the province and local municipalities. And during the 1988 election campaign, a major commitment was made to clean up the St. Lawrence River, a commitment which can only be met if significant funds are made available for the improvement and installation of sewage treatment facilities throughout the St. Lawrence Valley.

Thus, on the national platform, the government has maintained only opposition to our suggestions; in the context of regional announcements, it has committed to such substantial and useful contributions as I have just outlined.

We need not be puzzled by this ambivalence. Such is the subtlety of Canadian politics, that it makes sense for politicians to boast of doing the right thing in a regional context, while denying on the larger national stage that they are doing these things at all. You see, if others know that dollars are committed to one municipality, they might demand something for themselves, and then a government might be forced to take decisions in the context of a national program, rather than that of political expediency. A healthy beginning in the infrastructure dialogue would be for the federal government to acknowledge that it is already a financial contributor to Canada's municipal infrastructure needs, and will undoubtedly continue to be so as long as the public continues to establish the national agenda through the ballot box.

PUBLIC OPINION

And if ever there is an opportune time for federal political leaders to acknowledge their actions, it is now; for the public mood with regard to the environment has never been more informed. Canadians demand action on environmental issues. It is no longer acceptable that in Ontario 138 of 371 sewage treatment plants are not meeting provincial and environmental standards. It is outrageous that major Canadian cities on the East Coast have no sewage treatment plants whatsoever, discharging their entire sewage flow directly into their harbours. It is no longer acceptable that several West Coast plants fail to meet provincial standards. It is unforgivable that even here in Edmonton, the capital of progressive Alberta, the sewer system is badly outdated that it gives rise to serious leakage and overflow problems. Canadians do not accept these situations. Municipal governments cannot provide all the answers. The provinces cannot provide all the answers. Only with a full public sector commitment involving all levels of government will these needs be met.

THE NEW MOOD IN OTTAWA

But happily there is a new mood in Ottawa. There is a new optimism, a new commitment to environmental protection. I am persuaded that political realities are such that the Government of Canada will once again be a financial participant, helping do a job that Canadians know must be done.

When we had the conference on this subject 2 years ago, the main speaker for the Government of Canada was the federal Minister of the Environment, the Honourable Tom McMillan. Mr. McMillan delivered a tough message to us in Toronto. Let me quote from his speech:

> "Fact: only 10% of all raw sewage east of Ontario is treated. Fact: more than 8 million Canadians, a third of the entire population, live in municipalities that do not provide sewage treatment. Fact: water quality in Toronto, Canada's largest city, is causing so much concern that some politicians are calling for a $200 million pipeline from the Georgian Bay to serve the City. Fact: water quality has become such a concern to Canadians that they spent $80 million on bottled drinking water in 1986. That figure is expected to increase by 15% this year. Fact: the value of our water treatment and delivery systems now totals a staggering $100 billion. The bill for the next five years for repairing aging underground pipes alone has been estimated at $3 billion, with an additional $3 billion needed to improve water and sewage treatment facilities. No level of government in Canada is budgeting for rehabilitation programs of that magnitude."

But these facts did not move Mr. McMillan to meaningful action. He underlined again and again that no funds could be expected from the federal government for this work. He pointed to user charges as a necessary response.

USER CHARGES AS A PARTIAL RESPONSE

In this matter, Mr. McMillan had a point. Water pricing by municipalities is inconsistent across Canada. FCM must work hand-in-hand with its members to rationalize water pricing and ensure that in future the cost of water charged to the public is more consistent with the cost of delivering and treating it. But user charges alone are inadequate. The fact is that in some municipalities the cost of water would need to exceed current property tax levels in order to generate the funds necessary for water and sewer infrastructure.

LET'S BE CONSISTENT ABOUT USER CHARGES

There is a flip side to the Government of Canada's user pay theme worthy of reflection. FCM's research found the most neglected municipal infrastructure systems were in the transportation sector, particularly roads and bridges. If user pay is such a fine approach on the water and sewer side, as suggested by Mr. McMillan, then let us be consistent and levy fees on the users of transportation systems. The point of entry is, of course, fuel tax. The Government of Canada, as we know, levies heavy taxes on the users of gasoline and diesel fuel, but channels none of these revenues into our road systems. FCM is looking seriously at water rates. How about a quid pro quo from Ottawa through consideration of earmarking some of its fuel tax revenues for municipal roads?

LET US DROP THE CONSTITUTIONAL ARGUMENT NOW AND FOREVER

Mr. McMillan pointed to the constitution as another excuse for federal inaction. The constitutional argument is that urban infrastructure is not a federal concern. By the same token, the constitution provides no role for the federal government in health care, in social services, or in education, but nevertheless is a major contributor to our hospitals, to our institutions of higher education, to our health insurance systems, and to our social assistance programs. Let us transcend this constitutional argument now and forever in favour of agreement between the federal government and the provinces. The opportunity for agreement on infrastructure is ripe.

THE FEDERAL DEBT

Mr. McMillan talked about the sea of red ink in which our federal government is drowning. May I offer this comment. As long as Canada puts a higher priority on unemployment insurance and social assistance than it does on generating meaningful jobs for people who want them, we will always be afloat in a sea of red ink. To put this in other terms, it makes no sense to maintain over one million Canadians on our unemployment rolls when important work is waiting to be done. Something is wrong with a society that has people, who would rather work, lining up on a crumbling sidewalk to collect their UIC benefits. Capital investment is a prime opportunity for job creation.

The program we have proposed will create 330,000 person-years of employment over its 5-year lifespan. Ninety-nine percent of Canadians would rather work than not work. As a society we have an obligation to give these people the opportunity to work.

But the fact is, the program we have proposed is not expensive. We are looking to the federal government for $1 billion a year over 5 years. That represents about 3 percent of the current annual deficit and less than 1 percent of annual federal spending. The Minister of Finance's comment that our proposals, if accepted, would force up interest rates is not convincing.

LET OTTAWA TELL US WHAT IT CAN DO

I mentioned earlier the thaw in our discussions with the federal government. Senior ministers have told us recently that we should consider reformulating our position. The government has responded with a clear "no" to our original proposals, but they say, should we wish to put forward another proposition, it would be considered. I will recommend to our National Board of Directors that we not accept this invitation. If the numbers we have put forward are not acceptable to the Government of Canada, then let them tell us what numbers are acceptable. If $1 billion is too much for the first year of the program, let the government suggest another number. If our proposal for a catch-up program is too aggressive, then let the Government of Canada propose something with which it feels more comfortable. There is no magic in our suggestion of a 5-year effort. A smaller program spread over more years than we had originally contemplated would be helpful. If the Government of Canada cannot accept our proposals, let it first make counter-proposals before we amend our position.

INFRASTRUCTURE AND FREE TRADE

The Free Trade Agreement ought to be another major motive for federal action. The Agreement establishes a level playing field for investors. Industry can locate anywhere in Canada or the United States without fear of exclusion from the market of the other country. Industry is now in a position to make decisions solely on the basis of the comparative advantages of various locations, without concern for tariff barriers. Many people believe that the southern United States will attract more industrial investment than Canada because of their low labour costs which result from lower levels of social service, lower taxes, and an absence of labour organizations. But Canada, too, has comparative advantages. We have cities and towns where the quality of life is excellent, where the streets are safe, and where the infrastructure, despite our mounting troubles, is still better. We believe that some investors will choose Canadian cities and towns because of their quality, because they are in good condition comparatively , and because they have the water supply, the road systems, and a clean environment which are, compared with some United States cities, appealing. If Canada allows its municipal infrastructure to decline to the levels that we witness in so many U.S. cities, then we will lose a major competitive advantage.

WE DO NOT HAVE ALL THE ANSWERS

I do not pretend that FCM has all of the answers to all of the questions that our proposal has precipitated. We do not have a quick answer to a city which argues that its infrastructure is in excellent repair and that it has no need for additional funds. Our research suggests that the condition of infrastructure does not vary widely across Canada, but clearly there are exceptional cases. We can only state that we are wedded to equity. The FCM maintains that the program must be available to all municipalities, but we do not have any easy answers to ensure that all municipalities will benefit equally. We have not developed a detailed implementation strategy. Our main goal has been to highlight the need and to call for cooperation. Frankly, it is quite useless to develop an implementation strategy before all of the partners have come to the table. Two partners are at the table waiting to talk business with the third, but until that third partner arrives, we would be wasting our time developing detailed plans. Moreover, the third partner will undoubtedly have its own ideas on implementation.

The next step is clearly to get all partners to the table. Once that is achieved, we can begin to sort out some of the issues surrounding implementation.

CHALLENGE TO PROVINCES, TERRITORIES, AND LOCAL COUNCILS

So I challenge today all provinces and both territories to increase the energy and the commitment with which they are carrying this issue to Ottawa. We urge Premiers to make it a top priority in their discussions with the Prime Minister. And we urge municipalities across Canada to invite their Members of Parliament to a council meeting at which the infrastructure needs of their communities can be articulated. Local leaders share an obligation to ensure that every Member of Parliament in Canada understands how this issue affects his or her community.

GOALS OF THE CONFERENCE

1) We must update our information about the state of Canadian municipal infrastructure. Our current data was assembled through a survey conducted in 1984. We need to renew our understanding based on the latest information. We must determine whether the situation has improved or deteriorated. Our suspicion is that it has deteriorated.

2) We must keep the concern for the infrastructure in the public eye. This conference has already captured public attention and brought the focus of the media on this issue once again. Subsequent conferences will be held in other regions.

3) We must enhance our dialogue with the provinces and with the Government of Canada.

   In this respect I thank sincerely the Department of Municipal Affairs of Alberta and its Minister, the Honourable Dennis Anderson, for its financial contribution to this conference. I thank also the provinces of Manitoba and Saskatchewan who are represented here through their Deputy Ministers of Municipal Affairs. Their presence ensures that our efforts will be harmonized with the aspirations of the provinces as fully as possible.

4) We must exchange information about management techniques and techpnologies which will allow municipalities to deliver a high-quality infrastructure at the lowest possible cost.

   The FCM has never purported that the management of Canada's municipal infrastructure is perfect. There is room for improvement. If we are seeking the help of other governments in the task of maintaining infrastructure, we have an obligation to ensure that our management systems are highly developed and that the technologies we employ deliver the best product with the greatest economy. In this respect I thank those many municipal engineers, academics, and private consultants who have contributed so many useful papers to this conference.

5) We seek to renew municipal support for our efforts.

I have already stated that on no other issue has municipal solidarity been stronger. But we must keep this solidarity at the highest possible level. Collectively, Canada's 40,000 local politicians constitute an enormously effective communications instrument. Their collective efforts will guarantee our success.

6) Last and not least, this conference will serve to enhance our dialogue with federal officials.

We regret that Mr. Bouchard is unable to be with us, but accept his commitment that he will participate in subsequent events and welcome the many officials of his department who have joined us. We look forward to receiving his message, and although we do not expect a major change of position at this time, we are persuaded that Mr. Bouchard intends to take his role as Minister of the Environment very seriously. Signals to this effect have been emerging from Ottawa daily. The Prime Minister and Mr. Bouchard have made it very clear that environmental protection has a new priority and that the Government of Canada will measure environmental benefits in all of its decisions to a much greater degree than it has done in the past. With this new commitment I am more than ever persuaded that we will realize our overall goal, namely that of enhanced intergovernmental cooperation on municipal infrastructure, at an early date.

OPENING LUNCHEON

MUNICIPAL INFRASTRUCTURE: THE FEDERAL PERSPECTIVE

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ABSTRACT

For several reasons, the federal government discontinued its "banking" role of urban rehabilitation projects in November 1980 and has no plans of resuming that role now. Instead, the federal government chooses to function within the dictates of the Federal Water Policy which, for example, advocates realistic pricing for the supply and treatment of water, and promotes, through the Wastewater Technology Centre, the type of research that can improve cost effectiveness of the operation of some urban infrastructures.

RÉSUMÉ

Le gouvernement fédéral a renoncé, pour plusieurs raisons, à son rôle de constituer des "réserves" de projets de rénovation urbaine en novembre 1980, et n'entend pas non plus le reprendre à ce stade-ci. Le gouvernment fédéral choisit plutôt de s'en remettre aux énoncés de la politique fédérale relative aux eaux qui, par exemple préconise l'établissement de prix réels pour l'approvisionnement et le traitement de l'eau, et favorise, par l'entremise du Centre technique des eaux usées, le genre de recherche susceptible d'améliorer l'efficience de l'exploitation de certaines infrastructures urbaines.

(I bring you greetings and best wishes for the success of the Conference and workshops from the Honourable Lucien Bouchard who has been appointed the Federal Minister of the Environment. Mr. Bouchard regrets that he is unable to attend in person, but felt that it was extremely important that the Department be represented. He also considered that this conference was a unique opportunity to inform you of recent developments in municipal infrastructure.)

As you know, this federal portfolio, created almost two decades ago, has assumed greater importance in recent years as Canadians have grown to understand the interrelationships between our environment, our economy, our social progress, and our everyday activities.

At first glance, the infrastructure issue appears to be about rusty pipes and valves and malfunctioning treatment plants, pot-holes in roads, broken bolts on bridges, inadequate street lighting, and the like, essentially things that only money can fix!

Probing the issue deeper, particularly the water and sewer aspect, we find that, at the federal level, it is not that simple. There are, rather, a myriad of sub-issues: federal/provincial constitutional responsibilities, federal/provincial fiscal relations, federal deficit reduction, health, environmental protection, municipal finance, water resource management, regional economic growth, employment, technological research and development, better planning and management of existing systems, etc. The debate of the federal role in municipal infrastructure has been a prolonged and, on occasion, a difficult one.

In 1961, when CMHC introduced its financial assistance program for main trunk sewers and treatment plants, the purpose was to enable new sub-divisions to be developed to meet housing needs. Employment was also a short-term consideration, but the anticipated recession never developed. Various changes in the CMHC program took place subsequently, principally to allow opting for the "grant" openly, rather than the loan and forgivable grant of the original scheme.

Throughout this period there was considerable divergence of views. The federal government felt that it has been reduced to a "banking" role with little opportunity to influence priorities or planning while the provinces decried federal intrusion into provincial jurisdictional responsibility.

The short-lived community services assistance program of the 1979 - 1980 period further formalized the "banking" role by lumping together the municipal infrastructure and several other CMHC programs, and providing for "bloc-funding" to the provinces to carry out their intent.

The termination of the program in November 1980 by the then government marked the end of almost two decades of federal assistance, during which time some $2 billion in loans and $750 million in grants were made available for municipal infrastructure.

Among the reasons given for discontinuing the program were: the matter was a provincial constitutional responsibility; the federal government could not be fiscally accountable for the funds which it raised through federal taxes, but which were spent by other governments; there were other ways in which the federal government could use these funds to achieve its objectives; and the federal government faced budgetary restraint.

Since 1980, there has been no general program of federal financial assistance for water and sewer infrastructure. It is true that a number of programs which co-existed with the CMHC program, such as job-creation and regional development, continued to provide assistance, but this has been on a selective basis and has focused on the objectives of those programs.

In 1984, the Federation of Canadian Municipalities (FCM) released its proposal "Work, Work, Work" for a $12 billion program for the repair and upgrading of municipal infrastructure, to be shared equally by the federal, provincial, and municipal governments. That proposal, now estimated to cost $15 billion, included roads, bridges, and sidewalks, with water and sewer systems accounting for about one-half of the estimated cost.

There were a number of interesting aspects to the FCM proposal. First of all, the expanded title of the proposal was:

"In Municipal Services Work
The Economy will Work
Putting Canadians to Work"

The suggestion was that municipal infrastructure is central to the functioning of the national economy. Further, an FCM-sponsored study claimed that the federal "share" would be returned to its coffers through fiscal recapture.

The executives of FCM and their various presidents are to be commended for bringing the deteriorated state of our municipal infrastructure to the attention of the public and to municipal taxpayers. The FCM and the mayors of many municipalities have been persistent in keeping the issue in the public eye and, as a result, sewer and water systems now rank as one of the more important issues in today's municipal politics.

In hindsight, the magnitude of the federal deficit and the priority which the federal government would give to its reduction may have not been fully appreciated by other levels of government.

Most of you in the audience, and certainly those who attended the First Canadian Conference on Urban Infrastructure in Toronto in February 1987, are aware of the federal response.

At that time, the Honourable Tom McMillan, the former Minister of the Environment, announced that the federal government did not intend to restore previously dismantled municipal programs. This policy is still in effect.

The question that remains is, where does the federal government fit in?

The Federal Water Policy identified five functions as being within the federal ambit as far as water and sewage infrastructure is concerned.

- participate with provinces in cost and pricing studies;
- advocate realistic pricing;
- ensure good practice with respect to federal facilities;
- promote research, development, and transfer of wastewater treatment technology; and
- consider infrastructure projects that meet federal and provincial priorities under existing federal development programs.

On the matter of pricing, Environment Canada, in cooperation with provinces and municipalities, periodically surveys and publishes data. The Water Advisory Committee of the Canadian Council of Ministers of the Environment has also looked at this subject. Later on, in the Conference Program, you will hear from an Environment Canada official on these study results in more detail. Although it is unlikely that these studies will find the magic formula applicable universally to all Canadian municipalities, I think that the studies will be rewarding to municipalities in dispelling myths, in illustrating price impacts, and in suggesting how realistic and sensitive pricing systems can be designed and applied.

Internationally, Canadian water prices are low, ranking 13th among 14 developed countries. The average monthly water bill, including waste treatment, for a typical Canadian family of four, is about $16.00.

Since the annual quantity of water pumped by Canadian municipalities is 5 billion m^3, a doubling of water rates would raise about $2 billion a year, and the $7.5 billion estimated to be required for water infrastructure repair and upgrading could be raised in a short time.

It may surprise many of you that the federal government has water supply and wastewater problems of its own - whether as a result of its jurisdiction or its land and property holdings. Where federal installations are within the confines of an organized municipality, water and sewer services are usually purchased through grants-in-lieu-of-taxes and other arrangements with the municipalities. In other cases - certain defence establishments and national parks, for example - the federal government is often directly responsible. Overall, the federal government must continue to fulfill such responsibilities.

The federal government, through Environment Canada's Wastewater Technology Centre, is already active in researching and promoting technological development for the treatment of municipal and industrial wastes. With a federal budget of $2.5 million, it currently attracts another $2.5 million, with the additional amount being provided by other funding agencies and interests.

In cooperation with the Canadian Water and Wastewater Association, the Centre is sponsoring a series of workshops across Canada on technology transfer. It is tackling the research and development problem in a number of ways: computer control, high-rate biological treatment, improved chemical treatment, improved industrial waste treatment, and the disposal of residues, either through their use as fertilizers or in recovery of oil from sludge.

These advances are not just technologically more efficient, but can generate real cost savings. Capacities of existing waste treatment plants can be increased by including sensor-based monitoring and automated controls. In Kitchener, Ontario, for example, it was determined that a plant expansion planned because of stricter pollution control legislation could be postponed. A modest expenditure of $500,000 to upgrade and automate it could defer a $20 million plant expansion to beyond the year 2011.

Finally, under very specific circumstances, municipal infrastructure projects could be eligible for consideration under federal/provincial programs where the programs' objectives and the priorities of the federal and provincial governments are satisfied. Needless to say, any infrastructure proposals have to compete with other projects because demands for such funding also comes from a variety of other sectors.

A number of these were brought together under the Canada-Nova Scotia Agreement on Halifax-Dartmouth Area Development. That agreement, signed by the Atlantic Development Opportunities Agency, will provide up to $75.5 million of federal funds for sewage treatment in the area. Its objectives, however, are not only to enhance the regional development of the area, but also to exploit the new technology of converting domestic sludge to oil and to encourage private participation in the possible ownership or operation of the new treatment facilities.

We, in the federal government, as well as those in municipal and provincial governments welcomed the creation of the Canadian Water and Wastewater Association to deal with the water and sewer component of municipal infrastructure. Environment Canada is cooperating with that association on a study dealing with water metering. The association and our Wastewater Technology Centre are also co-sponsoring a number of regional seminars across Canada on "What's New in Wastewater Technology" in order to ensure that knowledge of the latest technical developments is made available to municipal engineers and others.

MUNICIPAL WATER PRICES IN CANADA: CURRENT RATES AND LEVELS

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ABSTRACT

This paper presents the results of a study of municipal water rates and prices in Canada, undertaken as part of the Inland Waters Directorate's socio-economic research. The analysis is based upon the results of a survey of 800 Canadian municipalities, approximately 500 of which returned usable data, principally in the form of water rate schedules for 1986. Topics of analysis included the structure of current water rates, water prices in the first and last blocks of rate schedules, the size of blocks in the rate schedules, marginal water prices, and the total price of monthly water supplies to customers. The study deals only with direct water charges to customers through periodic billing, and does not include the various indirect financial supports which may apply in various areas, such as the use of general tax revenues and transfers from senior levels of government.

Principal findings were that

- the majority of water consumers in Canada face flat or quasi-flat rates,
- unit costs of water tend to be very low,
- the "width" of initial blocks in the rate schedules of many areas is quite large (which effectively creates flat-rate pricing conditions), and
- the average monthly price of water across all municipalities in 1986 was about $16.00 per family.

The paper concludes with a discussion of some of the policy-related implications of the study, and suggestions for improving current pricing practices within the context of financing water infrastructure upgrading.

Note: The views expressed in this paper are those of the author alone, and not necessarily those of the Government of Canada.

RÉSUMÉ

L'exposé livre les résultats d'une étude portant sur le prix de l'eau dans les municipalités canadiennes, entreprise dans le cadre d'une recherche socio-économique de la Direction générale des eaux intérieures. L'analyse so fonde sur les conclusions d'une enquête effectuée auprès de 800 municipalités canadiennes, dont environ 500 ont transmis des données exploitables, surtout sous forme de grilles de tarifs pour 1986. L'analyse portait notamment sur la structure de la tarification en vigueur, le prix de l'eau dans la première et la dernière tranches, de la grille des tarifs, la taille des tranches, les prix marginaux de l'eau ainsi que le prix total de l'alimentation mensuelle en eau acheminée vers les consommateurs. L'étude s'intéresse uniquement aux frais directs imputés aux consommateurs par voie de factures périodiques, sans égard aux diverses subventions indirectes, comme l'utilisation des recettes de la taxe générale ou les transferts en provenance de paliers supérieurs de gouvernement, applicables dans différentes régions.

Les principales conclusions s'expriment comme suit :

La majorité des consommateurs d'eau, au Canada, font face à une tarification forfaitaire ou quasi-forfaitaire; le coût unitaire de l'eau se révèle généralement très bas; la "largeur" des premières tranches, dans de nombreuses régions, revêt assez d'importance (ce qui suscite effectivement une tarification forfaitaire); et, en 1986, le prix mensuel de l'eau revenait en moyenne à 16 dollars par famille dans toutes les municipalités.

L'exposé se termine par une discussion de certaines répercussions de l'étude sur le plan des lignes de conduite, et par des suggestions tendant à améliorer les techniques actuelles de tarification, en associant cette pratique à la nécessité de relever la qualité des infrastructures hydrauliques.

Nota: Les opinions que l'auteur exprime ici ne reflètent pas nécessairement celles du gouvernment du Canada.

INTRODUCTION

The issues posed by the need for urban infrastructure repair and upgrading have formed an important part of the Canadian water management agenda for the last several years. I believe that the need for renewal is well-established, although the precise magnitude of the task and the means for accomplishing it require further discussion. This paper is intended to shed some light on current economic practices in municipal water management.

Specifically, the paper addresses two issues. The first and principal one is to outline the findings of a recent study of water rates across Canada (Tate, 1988). The second is to provide an economist's interpretation of these findings and their implications for infrastructure financing and future funding stability.

The approach used is based upon the philosophy of "demand management" applied to water resources. Basically, this philosophy holds that water use is a demand, which is influenced by price - just like any other market good or service. This philosophy, which is well grounded in research that has been conducted over the last three decades, forms the basis of the management position that water use can be influenced substantially by realistic pricing practices. The demand management approach contrasts sharply with the widely held view that the use of water is a requirement of society that must be met regardless of cost.

Our work in this area began in 1983, when the Organization for Economic Cooperation and Development requested information on municipal water-pricing practices in Canada. This request required the collection and partial analysis of municipal water rate schedules for some 500 municipalities across the country. This initial assessment found a very diverse, inconsistent, uneconomic, and often bizarre set of water pricing practices across Canada. Within the Inland Waters Directorate (IWD), this type of basic research was found to be valuable in our general socio-economic program and the survey was repeated in 1986, thanks to the generosity of municipalities for providing data at about that time, the FCM published its infrastructure report. Environment Minister Tom McMillan addressed the federal position on the main funding recommendation of this report at your first conference, and I will not rehearse the arguments in support of this position. As part of the federal offer to conduct research in the field, IWD was instructed to undertake a major study of current water rates and their implied water prices to consumers. The completed study forms the basis of this paper.

MUNICIPAL WATER-PRICING PRACTICES AND RATES

The pricing study examined retail water rates, and the water prices that follow from them. Theoretically, prices to consumers act as "signals" regarding the value of the resources they are using. For example, the case of energy prices is illustrative. In the 1960s, energy was cheap, reflecting the basic fact that the resource was considered plentiful and extraction inexpensive. We all know that the real price of energy has climbed substantially since then and that energy consumption has fallen accordingly. The important lesson here is that that reduction did not cut into "essential" uses of energy, but reduced waste and improved efficiency. The analogy between water and energy is not perfect, of course, but the basic mechanisms of increased price, lowered demand, and improved technology are the same. This is basic economics at work.

In general, it is well established that goods tend to be used extensively the lower their price, and that their use falls as price rises. This idea of prices as "signals" to consumers is an important one. If the price signals reflect the value of resources being used accurately, the resource tends to be used rationally. But, if they undervalue the resource, the resource tends to be overused or, to put it plainly, wasted. Using economic principles, Millerd (1984) showed that commodity prices based on marginal costs of production are considered the most efficient means of pricing. Marginal cost here simply means the cost of producing an extra unit of the commodity. For example, marginal cost of an extra unit of water supply would be the cost of a system expansion averaged over the increased water pumpage that would be provided. Hirschleiffer *et al.* (1960) used this "marginal cost pricing" criterion to recommend the way in which municipal water prices should be set. After about three decades, this method of pricing is still being resisted, but is nevertheless still valid theoretically.

With this background in mind, the research examined two principal questions: "What are the economic characteristics and general levels of municipal water prices across Canada" and "Are water use and water prices related?" The concern was not to account for the complete economic structure of the municipal water industry. Thus, the matter of indirect subsidies to water systems, for example, from provincial levels of government, were not considered. This is a limitation of the research in the sense of completeness, but it does not detract from the findings about the prices which consumers face for their water supplies.

The project proceeded from a short survey asking municipalities for a copy of their currently applicable water rates. The survey covered all municipalities with a population of over 5,000, plus a 10 percent sample of those between 1,000 and 5,000. The "survey universe", accordingly, consisted of about 800 municipalities. There were 150 non-respondents. As expected, the rate methods and details were exceedingly diverse across the country. About 180 municipalities had rates based on property assessments, frontage, and other parameters unrelated to water use. These rates were discarded, because these data are unsuitable for analysis. (In should be noted in passing that these discarded rates would fall almost entirely into the "flat rate" category outlined below.) This process of discarding, combined with the non-respondents, left about 470 municipalities for analysis, containing 62 percent of the total Canadian population.

Characteristics of Municipal Water Rates

To answer the first question, concerning the characteristics of municipal water rates, the study derived several common parameters from the primary data. First, the overall type of structure for each rate schedule was allocated to one of four types: flat rates, declining block rates, constant unit rates and increasing block rates. These categories were selected because they are the most common types of rates in use, and they also serve as indicators of the potential of water rates to encourage or discourage water conservation (Table 1). Second, minimum charges or minimum volumes of water included in the initial blocks of the block rate structures were determined. Third, the number of blocks in the rate structure was recorded, along with the charge per cubic metre for water in the first and last blocks of the rate structure, and the width of these two blocks. Fourth, the marginal cost of an extra cubic metre of water at a specific level of monthly usage. Finally, to compare water prices across the country, the monthly price to consumers of three standard volumes of monthly water use, 10 m^3, 25 m^3, and 35 m^3, was calculated.

Relationship Between Price and Water Use

To answer the second question, concerning the relationship between price and water use, linear regression analysis was used to test the strength of the hypothesis that the level of municipal water use is a function of price. For this analysis, the monthly cost of water at the 35-m^3/month level (the independent variable) was used to "explain" total annual water pumpage (the dependent variable). The pumpage data were obtained from a database compiled earlier. The level of monthly water usage selected represented the monthly water use of a typical Canadian family.

Table 1

Types of Rate Structures

Type	Description	Conservation Potential
Flat Rates	Customer pays a fixed rate per time period for unlimited access to public water supply	None; encourages excessive use
Declining	Water use is divided into two block rates or more volume ranges or blocks; the rates decline progressively for water use in the larger blocks	Progressively decreasing as water use increases
Constant Unit	Charges per unit of water use (e.g. cubic metre) are constant through the range of usage	Moderate to good
Increasing Block Rates	Similar to declining block rates, except that rates increase progressively through the range of usage	Progressively increasing as water use increases

The 1123 residential and commercial rate schedules exceeded the number of municipalities in the study by about 2.5 times. About 37 percent of these schedules were flat-rates schedules whereby the customer gained unlimited access to the municipal water supply in return for the payment of a flat fee. Many of the largest cities in Canada, including much of Metro Toronto and other cities, such as Calgary, fell into this category. Municipalities on the coasts and in Quebec tended to use this type of structure most frequently. About 34 percent of the rates were of the declining block rate type. Most of the remaining rates (27 percent) were of the constant unit rate type, while 2 percent were increasing block rates.

Most of the volume-based schedules included a meter charge and about one-third used some form of minimum monthly billing. In some cases, the volume of water included with the minimum bill was large enough so that the customer could use as much water as demanded and still pay only the minimum bill. In other words, flat-rate pricing conditions prevailed. The number of blocks in a typical volume-based rate schedule was three, but ranged up to 11.

Prices per cubic metre per month averaged 38 cents for those volume-based schedules using a constant-unit price format. For block-rate formatted schedules, the unit prices in the first block averaged 48 cents/m^3, falling to 29 cents in the last block. This decline typifies a dependence on declining block rates.

As noted earlier, economic theory suggests that consumption of an extra (or marginal) unit of a good or service depends upon the price of that unit, and further that the price of the marginal unit is the price which should be set for the commodity. We compiled the marginal price of water at the 35-m^3 level of usage, and found that it is generally below $1 and nationally below 50 cents. These low prices imply that consumers would have very little incentive to curtail their use of water, and that water wastage may be occurring.

By computing the hypothetical price that a consumer would pay for water in each municipality, one can compare water prices across the country. This illustration uses the 35-m^3/month level of usage, although other levels are also provided in this paper. The mean residential price of water (including sewer surcharges) was $16.08, reaching lows in the coastal areas and Quebec, and highs in the water-short prairies and the Territories. Ontario is about in the middle of the range. Median prices generally fell below the mean indicating that more rates fell below provincial averages than above, a fact also borne out by the unit water prices. Commercial water prices tended to be a little higher than the residential ones.

Finally, we found an inverse relationship between water use and price. Cross-section analysis of the data provided measurements of demand elasticity for municipal water services across Canada. It was found that for each 1-dollar increase in the price of an additional cubic metre of water used per capita-year in all the municipalities included in the analysis, water use would decline by close to 46 percent. This amount varied from a high of 76.5 percent in B.C., where flat-rate pricing is currently the favoured practice, to a low of 21 percent for Ontario, where water is already generally priced on a volumetric basis. A price increase of $1/m^3$ represents a tripling of current average prices, which now stand at about 47 cents. It is also significant that a $1 increase per cubic metre per capita-year would lead to a 59-percent reduction in water use in communities with a population of over 100,000. All of these figures are statistically significant at the 95-percent level.

DISCUSSION

The findings shed light on some of the problems of financing in the water infrastructure area. Water rate structures, unit and marginal prices, block sizes, total prices to consumers, and the overall demand relationships found in the data all constitute points for discussion.

As noted before, rate structures form an implicit incentive for water overuse or conservation, depending upon their form. The flat rates (37 percent of the total number) contain absolutely no incentive for conservation. This is borne out by previous research findings (e.g. Kellow, 1970) that water use in communities charged a flat rate is twice (or more) as high as that in communities with volume-based rates. The declining block rates (34 percent) give some incentive for lower water use, but the incentive varies inversely with volume, and they do not encourage conservation. Many of these rates contain wide initial blocks, effectively presenting users with flat-rate conditions. Thus, over 70 percent of the rates actually promote the overuse of public water supplies.

Throughout the country, unit water prices are uniformly low. Economists may cringe at the next table, but it illustrates plainly how low these prices are. Average water price at the 35-m^3/month level is $0.47/$m^3$. The next cheapest common liquid, cola, is about 1,500 times more expensive!

As noted earlier, the marginal price of water nationally is under 50 cents. Few persons will pay any attention at all to water usage when such a pricing condition prevails.

Table 2

Typical Prices for Popular Liquids

Liquid	Cost ($/m^3)
A. Beverages	
Tap Water[1]	0.47
Cola	787.00
Milk	900.00
Perrier Water	1,333.00
Beer	2,000.00
Wine	6,000.00
Whisky	18,000.00
B. Gasoline	550.00

[1] Based on the Canadian monthly water price of 35 m^3.

Note that all beverages except water have to be collected by the consumer, whereas water is delivered to the home and wastewater is removed at no inconvenience to the consumer.

For volume-based rate schedules, block sizes form an interesting characteristic. If, for example, the first block of a rate schedule is sufficiently large, the ordinary customer will never reach the second block and will, in effect, pay a flat rate. This is precisely what happens in Canada. Only in Alberta does the average size of the initial block fall under the average monthly water use for a typical family of four persons. The first block size can range up to 8,000 m^3/month, about 230 times the average family's monthly water use. This fact indicates that, in spite of having volume-based pricing, flat-rate conditions *de facto* may pertain.

Average prices to consumers totalled just over $16.00 per month. Prices tended to be higher in the three prairie provinces, perhaps reflecting the relative regional water scarcity. They tended to be lower on the coasts, where some monthly prices under $4.00 per connection were found. Prices did not follow any pattern with respect to system size, indicating that if economies of scale do occur, they are not being passed along to consumers.

Turning briefly to a more general interpretation of these findings, the primary fact is that Canadian retail water prices are relatively low, and that consumers receive the wrong signals about the value of water used. To them, it is a cheap commodity which need not be conserved. Thus, water is viewed as a requirement to be met, not as a demand which can be changed through pricing practices. Artificially high demands inflate operating and maintenance costs, including significant energy costs. Prices fail to reflect the total costs of system construction, maintenance, and renovation. The deteriorating condition of water-related infrastructure is proof of this. Declining block rates or, even worse, flat rates fail to recognize that large water users are the ones who are primarily responsible for overall system capacity, design, and costs. Thus, in reality, there are implicit subsidies to large water users from the general public.

The actual situation is even more unfavourable than simple price-demand comparisons indicate. Because they are low, prices are rarely taken into account in projecting water demands. Many consultants and analysts assume a constant, or even increasing water use per capita, and then multiply these "coefficients" by projected population to generate projected water "requirements" in the future. These requirements then become design parameters, and lead to systems being expanded or built which would be too large if water price were more reflective of actual resource values. Once these systems exist, they have to be used, which forms an incentive for keeping prices low, forcing another expansion of the system before it would be required if prices reflected actual economic conditions. Thus the cycle of low prices/high demands/over-building is self-reinforcing. This is a waste of scarce public resources; and by all indicators, unsustainable public resources. Postel (1985, p. 40) summarized this argument well by stating:

> "Planners have typically projected future water demands based on the historical rate of growth in per capita water use and the projected population. They then plan to meet this estimated demand by drilling more wells or

> building new reservoirs, and expanding the capacity of their water and wastewater treatment plants. Rarely have planners focused on reducing water demand as a way to balance the long-term supply/demand equation."

CONCLUDING REMARKS

This paper establishes that water prices across in country are quite low. Being a federal bureaucrat, I am aware of the constitutional niceties involved in water management in this country. These give the power to set and review municipal water prices to the local level of government, quite properly so. Thus, a federal public servant can only make observations and, based on these, suggest potential areas of improvement.

There is an acknowledged infrastructure repair and upgrading problem in Canada, and with it a significant financial problem. The best way out of this problem appears to be a substantial rise in water prices to consumers. This is not a penalty, but a way of minimizing social costs, which surely most be one of the aims of public officials. Annual water pumpage by municipalities is currently in the range of 5 billion m^3 (Tate, 1985).

Doubling water prices from their current level (i.e., about 50 cents/m^3) would raise $2 billion a year, allowing for the decreased demand that would accompany the price rise. Let's assume that the average monthly price of water per connection applies nationally. Such a policy would raise prices to just over $32.00 a month, a little more than the cost of a case of beer. With proper education and information programs, such a move, I suggest, would be saleable, especially given the priority placed on environmental issues by the public.

Given this overall objective, the next relevant question relates to the means for achieving it. First, universal metering is imperative. Without this, it is impossible to inform consumers effectively about the value of their resource use and municipalities have no rational means of charging for water servicing. Second, flat-rate pricing schemes should be abandoned. Rate structuring is quite a complex issue, and our studies in this area are not far enough along to provide any definitive answers. However, a 2-part tariff system appears to offer a good compromise between theory and practicality. The first part of the tariff would be a fixed charge to reflect the overhead costs of a utility. The second part would be a constant charge per unit of use, reflecting the marginal costs of operating the system. The unit charge would apply to all customers of the utility, and as noted, would be the marginal cost of operating the system. Marginal cost calculations are relatively easy to make (Hanke, 1978), and could be based on a multi-year operational plan to assure some measure of rate stability. All system cost components should be reflected in the marginal cost calculations. In some cases, such a pricing system might lead to small annual revenue shortfalls, which could be made up readily by increasing the subsequent year's water price accordingly. In any case, revenue shortfall would not be serious.

This system of pricing municipal water would have several beneficial effects. By allowing retail water prices to reflect more closely the costs of providing the service, consumers would begin receiving proper signals as to the costs of their water use. Allocation would thus become economically more rational. By construing water use in a demand-related context, expansions of the supply system would take place on an economically justified basis. By making large water users pay in direct proportion to their usage, and at a constant unit rates, recirculation would be encouraged. By basing water charges on full system costs, revenue adequacy would be assured. Finally, by realistic pricing, free of implicit or explicit subsidies, there would be a significant incentive for technological changes, such as water re-use, computerized control techniques, better detection of leaks, and other measures.

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CORPORATE OWNERSHIP OF WATER SYSTEMS

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ABSTRACT

The ownership of water services by investor-owned companies is an appropriate policy vehicle to promote both systematic and timely development. The privatization of water services offers an attractive opportunity for government to re-direct the future use of capital and public debt at both provincial and municipal levels.

RÉSUMÉ

L'appartenance des réseaux d'alimentation en eau à des sociétés détenues par des investisseurs constitue un véhicule politique tout indiqué pour favoriser un aménagement systématique et opportun. Leur privatisation offre au gouvernement fédéral une occasion intéressante de réorienter l'utilisation future des fonds et de la dette publique vers les paliers provinciaux et municipaux.

INTRODUCTION

In Canada, provincial and municipal governments have been responsible for the development and operation of public water systems. As a result of aging infrastructure, population growth, and industrial development, there is a growing need for water system renewal and expansion. Under current arrangements these facilities are provided at significant cost to the taxpayer, thereby increasing the financial burden which many governments already carry.

Solutions to this problem vary. In various parts of the world, governments are examining privatization programs as an appropriate policy alternative. Water system privatization would divest governments' construction, operations and ownership responsibilities to investor-owned, publicly- raded companies.

This paper examines the background, policy concerns, potential benefits and precedents of investor-owned water utilities.

CONCEPTUAL FRAMEWORK

In this paper, privatization is defined as the transfer of enterprises from governments to the business sector. Privatization arrangements are intended to complement fiscal and economic development policy goals of government while providing long-term investment business and technological skills in new areas.

In practice, privatization can take a variety of forms, including:

divestiture	transfer of ownership, control and operating responsibility of a legal entity;
devolution	transfer of services or activities previously delivered by government;
contract management	transfer of operating responsibilities of a legal entity without relinquishing ownership and control; or
contracting out	purchase of goods or services formerly supplied by government.(1)

Privatizing through divestiture would be applicable in the transfer of fiscal and operating responsibility for existing municipal or provincial water systems to business interests. Privatizing by either contract management or contracting out does not reduce the financial commitment that government must make to fund large capital investment projects.

In the case of corporate ownership of new water systems, government could grant a franchise to an investor-owned corporation to provide the service, with the corporation having title to the real property. The franchise agreement would embody the guarantees necessary to protect the public interest. Kay and Thompson (2) believe that in the case of natural monopolies, such as gas or water supply, franchising may also provide the opportunity to introduce the element of competition into the privatization process.

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(1) Konrad, J. E., "Does Privatization Make Sense?," Optimum, Vol. 17, No. 2, (1986), p. 82.

Emerging Financial Challenges

The report "Inquiry on Federal Water Policy"(3) puts the emerging problem of Canadian financing for water services into perspective:

> "Water supply and wastewater systems represent tremendous investment. Total replacement cost of Canadian waterworks and wastewater systems are estimated at $62 billion and $47.5 billion, respectively. This amounts to $3,000 per capita served.
>
> In 1984, an estimated $2.4 billion in capital cost alone was spent on providing new or upgraded service, but this is clearly insufficient to provide and maintain the facilities needed."

In Alberta, the task of providing for infrastructure development falls largely to municipalities, assisted by provincial grants. In the coming years, the provincial government will face increased pressure to shoulder more of the financial burden from communities and municipalities.

Clearly, the ability of governments to respond to these infrastructure requirements will be limited by the timely availability of necessary funds. The infusion of private capital could play a significant role in ensuring the systematic development of future water systems.

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(2) Kay, J. A. and Thompson, D. J., "Privatization: A Policy in Search of a Rationale," The Economic Journal, (1986), p. 25.

(3) Pearse Commission, Inquiry on Federal Water Policy, (1985), p. 102.

BENEFITS OF CORPORATE OWNERSHIP

Many jurisdictions have discovered that corporate ownership offers a broad range of benefits to the economy, the public, and government.

Corporate ownership of water services reduces demands on government time and resources currently involved in the development and management of water facilities, thus allowing government to concentrate on other priorities. Government would serve the public interest better in regulatory roles over utility services when it is not concurrently the financier or operator of those services.

Corporate ownership of water supply systems can provide additional benefits:

- introduction of criteria of economic performance to the water service industry;
- development of technically innovative solutions to water supply, treatment, and handling problems;
- facilitation of shift to a full user pay, or revenue dependency, status for water supply systems;
- creation of additional sources of revenue with new businesses contributing corporate and property taxes to municipal, provincial, and federal governments; and
- establishment of new areas of investment opportunity for individual Canadians.

THE PUBLIC INTEREST

When significant change is suggested, there is a tendency to adhere to the status quo in terms of how things are done and who does them. Apart from this natural tendency, two key issues particularly seem to affect the thinking about corporate ownership of water supply systems: the seeming complexities of regulation or other mechanisms to protect the public interest, and the concept of profit.

In Canada, many provinces have opted for government ownership and operation of utilities, while others have favoured regulated corporate ownership. In tracing the development of utilities in Canada, Gordon(4) concludes that:

> "The degree of government ownership of natural monopolies in Canada is clearly the result, to a considerable extent, of emotionally held political philosophies, fear of big interests, and — perhaps in early days — the absence of a regulatory authority in which the public could have confidence."

In the case of investor-owned and -operated utilities and services, the regulatory framework and procedures are becoming more standardized. The public interest can be protected by ensuring that corporations:

- adhere to requirements presented to them under a structured regulatory regime or through the terms of a contractual agreement;
- have substantial financial resources;
- exhibit sound management practices; and
- demonstrate corporate longevity and success in other regulated environments.

Corporate ownership of public services in Alberta is not a new phenomenon. Examination of the regulation and control of gas distribution and electrical utilities, inter-city bus and truck transport services, cable television and telephone services, and solid waste management provide examples of how the public interest can be served within the framework of corporate ownership.

The concept of corporate ownership also requires consideration of the profit component of the venture. A corporation that does not operate at a profit is destined to fail. A successful corporation will generate a profit which, in turn, is reinvested or paid out as taxable dividends. The return which would be earned on the equity investment comprises only a small portion of the total cost.

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(4) Gordon, M., Government in Business Natural Monopolies, Vancouver, C.D. Howe Institute, (1981), p. 43.

The spread between return on equity and debit interest rate will reflect relative risks, alternative investment opportunities, and financial market conditions at the time of financing. Assuming debt is on an actual cost basis, only the difference between the equity return level and debt interest rate can be called the "profit element". If that spread is 4 percent and the equity component is 40 percent of the total capital cost, the effect is an additional 1.6 percent of capital cost of the project to the cost of service.

CORPORATE OWNERSHIP OF WATER SERVICES IN CANADA

In Canada, corporate ownership of water supply systems is not presently extensive, but there are indications of future growth potential. As of mid-1986, more than 40 privately owned water supply utilities were operating in the country, serving about 75,000 people. Quebec, with 20 facilities in operation, is currently the Canadian leader in privately owned water systems.

Interest in the concept of water supply privatization has been growing in some areas of the country. In Alberta, the examination of corporate ownership of provincial water service systems is ongoing. Several Alberta municipalities are considering the sale of their water systems to nvestor-owned companies and have them operate the systems.

CORPORATE OWNERSHIP OF WATER SERVICES IN OTHER COUNTRIES

There have been several notable experiences with corporate ownership of water service systems in other countries, such as the United States, Great Britain, and France. A review of these experiences, based on an article by MacLaren(5), follows:

United States

In the United States, about 20 percent of the population is serviced by 200 private or investor-owned water utilities. Water companies in the U.S. are regulated by a state's public utilities commission. A typical capital structure for U.S. water utilities is 35 percent common equity, 5 percent preferred equity, and 60 percent debt.

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(5) MacLaren, J. W., Unpublished, Pearse Commission, (1985), p. 102.

The American Water Works company is the largest water supply company in the U.S., owning and operating a number of local systems in 19 states. It operates its business under state regulatory authorities which define its service areas and control the rate of return on the company's investment.

France

In France, five investor-owned utilities provide municipal water supply or wastewater disposal services. The three largest companies meet the water requirement of about 60 percent of the population. Employing more than 40,000 people, the companies retain qualified personnel in all professional skill areas which enables them to design, construct, and operate complex utility systems.

Great Britain

In England and Wales, water supply, wastewater, and storm drainage services are the responsibility of 10 regional water authorities. The authorities operate relatively autonomously under central government legislation and regulation. As a result of recent government initiatives, private companies are now supplying water to 20 percent of the population as agents of the regional water authorities.

The water authorities are self-supporting and must raise all needed revenues from their customers, with rates established on a full-cost pricing basis to permit full revenue dependency. Owing to the strong performance of the water authorities, government is rapidly advancing plans for the sale of the water supply and sewage functions to the corporate sector. One of the authorities which is actively seeking to be privatized is the large Thames Water Authority.(6)

INTERPROVINCIAL PIPE LINE COMPANY

The Interprovincial Pipe Line Company has entered the water services industry. Projects undertaken by Interprovincial will be financed, owned, and operated by it. This approach will provide a new standard of reliable and economic service.

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(6) Kay, J. A. and Thompson, D. J., "Privatization: A Policy in Search of a Rationale," The Economic Journal, (1986), p. 31.

Interprovincial Pipe Line is prepared to build, own, and operate water supply systems. With over 11,000 km of pipeline and 1,000,000 h.p. of installed pumping capacity, the company has a proven track record of planning, building and operating liquid pipeline systems in a fully regulated environment.

Company personnel have extensive experience in financing, planning, construction and supervision of major projects, dealing with broad public and regulatory issues, and providing on-going operations and system maintenance services in a safe, cost-effective, socially and environmentally responsible manner.

CONCLUSION

The ownership of water services by investor-owned companies is an appropriate policy vehicle to promote both systematic and timely development. The privatization of water services offers an attractive opportunity for government to re-direct the future use of capital and public debt at both provincial and municipal levels.

MUNICIPAL INFRASTRUCTURE REHABILITATION IN SASKATOON

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ABSTRACT

The program development in Saskatoon's ongoing maintenance activities lead to the formal identification of an overall infrastructure program. Also, put in place is an infrastructure reserve to ensure a fair and equal distribution of the cost of rehabilitation. In this program, the City has recognized the need for taking action and being responsible for its own infrastructure.

RÉSUMÉ

La création d'activités permanentes d'entretien à Saskatoon a donné lieu à la caractérisation officielle d'un programme général de réfection des infrastructures. Les autorités ont également décidé de constituer une réserve dans le but d'assurer une répartition juste et équitable des frais de remise en état. Par son programme, la Ville a senti le besoin d'agir et d'assumer la responsabilité de ses propres infrastructures.

HISTORY

The City of Saskatoon is the largest city in Saskatchewan with a population of 183,000. It covers an area of 145.21 km^2. The city maintains streets (877 km), watermains (820 km), sewer mains (711 km), and storm sewers (433 km).

In the late 1970s, the City of Saskatoon recognized the potential crisis in service delivery and cost both due to the deteriorating state of the infrastructure. Prior to 1980, the only programs for maintaining watermains, sewer mains, paved streets and sidewalks were maintenance programs for repairing breaks and visible failures or hazards.

Watermains

In 1980, a program was initiated to replace cast-iron watermains in which an excessive number of breaks was occurring. The purpose of the program was to eliminate high maintenance costs and inconvenience to the public.

There are approximately 820 km of watermains in Saskatoon, of which 294 km are of cast iron, installed during 1906 to 1973. Its use was discontinued after 1973. Since 1980, 18 km, or 6 percent, of the cast-iron pipe has been replaced under this program at a total cost of $6.7 million. Replacement of an additional 2.3 km is planned for 1989 at a cost of $1.2 million.

The replacements are partially funded by local improvement charges against adjoining properties. These charges are based on the current year's prepaid rate and, on average, covers 40 percent of the replacement cost. The prepaid rate is the cost of construction of new watermains (or other services) in a new development. The rate does not include street or sidewalk replacement which is required for the Local Improvement Program (LIP) (see Table 1).

In conjunction with the implementation of the watermain replacement program, a policy based on the following criteria was implemented:

1. Replacement of a watermain will be considered when the break frequency on any block is 5 breaks/km/year and the observed physical condition of the pipe indicates that this failure rate will continue.

Table 1

Annual Costs of L.I.P.

Year	Length (m)	Total Cost ($)
1981	1,131	310,000
1982	2,859	886,100
1983	891	353,900
1984	2,740	859,300
1985	3,824	1,436,600
1986	1,530	707,000
1987	2,586	1,119,900
1988	2,054	1,025,500
Total	17,615	6,698,300

2. The uniform rate to be assessed to the adjoining property for watermain replacement will be the current year's prepaid service rate.
3. Where the existing main was installed as a local improvement on which the adjoining property owners are still making payments, the city will absorb the annual charges until the original local improvement is paid up. Thereafter the charges will be assessed to the property owner.
4. Where the existing main is in a prepaid service area, the charge will be in proportion to the expired life of the watermain as has been determined by the city engineer.

Roadways

In 1980-81, an additional rehabilitation program, partially funded by Urban Assistance, was developed, applying only to arterial roads. The load-bearing capacity was measured by Benkleman beam and a structural pavement overlay (recapping) program was designed to bring the road up to required strength.

A second repaving program was added in 1984, providing for rehabilitation of collector roads by means of a thin lift overlay designed to protect the surface plus improve ride and drainage.

A third road repair program, begun in 1986, was applicable to and funded by recent prepaid areas. Pavement irregularities caused by the settlement of utility trench backfill are being corrected by a combination of injecting cement grout to stabilize the subgrade, then filling surface depressions with enough asphalt to restore reasonable ride and drainage.

The pavement management system was restructured in 1986 to evaluate and prioritize rehabilitation more definitively. The Benkleman beam was replaced with a Dynaflect machine which provides a more complete evaluation of pavement structure faster and more economically. A firm with a laser Road Surface Test (RST) machine was engaged to obtain objective data on surface condition. Computer programs were obtained which analyzed machine and other data to provide a comprehensive ranking on a block-by-block basis. Annual programs of rehabilitation are based on this information. The annual costs of the pavement rehabilitation are tabulated in Table 2.

Table 2

Annual Costs of Pavement of Rehabilitation

Year	Lane Length (Km)	Cost ($000)
	Arterial and Expressways	
1981	10.2	$ 578
1982	9.6	712
1983	11.8	993
1984	11.6	979
1985	13.6	797
1986	17.2	930
1987	12.5	1,200
1988	20.7	1,258
Total	107.2	$7,795
	Collectors/Locals	
1984	11.1	$388
1985	6.1	383
1986	10.2	607
1987	19.6	848
1988	17 04	895
Total	64.04	$2,860
	Prepaid	
1986	39.0	$1,000
1987	47.0	1,000
1988	26.0	500
Total	112.0	$2,500

Sewers

In the sewer main maintenance section of the early 1980s operating budget provided for the hiring of a contractor to film the condition of sanitary sewers. The contractor inspected 25 km of sewer a year.

In 1985, a capital project was initiated to procure our own camera. This camera is now used to identify emergency, short- and long-term requirements for sewer main repair and replacement. In addition, the quality of construction inspection has been enhanced with the use of camera inspection.

In 1984, a design project was initiated to look at a major storm sewer; in 1986, an additional project was initiated to look at storm water management in the north sector of the city.

LOSS REDUCTION

Watermains

The implementation of the watermain replacement program in 1980 has had a significant impact on the service level as indicated in Table 3 and Figure 1.

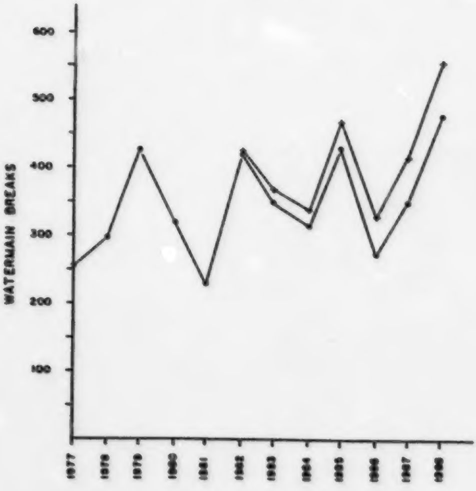


FIGURE 1: Watermain Breaks.

Table 3

Watermain Breaks

Year	Actual	Estimated Without Program
1977	254	N/A
1978	297	N/A
1979	426	N/A
1980	320	N/A
1981	229	N/A
1982	419	425
1983	349	369
1984	315	339
1985	430	468
1986	273	330
1987	351	416
1988	478	556

The ongoing loss reduction can be broken down as follows:

Quantitative Costs (per year)

Reduction in breaks	78
Estimated cost	$300,000

Qualitative Costs

Failure to provide service	$1,000 deductible
Flooding of private property	
Deterioration of roadway	

The qualitative loss is mainly felt by the local resident/taxpayer. Due to this, the need for the program cannot be related to the City expenditures alone. Each additional break can effect 30 or more residents or commercial operations thereby magnifying the loss.

Roadways

Streets for recapping have been selected on the basis of rank (see Table 4). The selection is, however, influenced by other factors, such as planned water and sewer projects (LIP) and such complementary projects as 51st Street twinning and Traffic Circle case/modifications. To date, only those streets requiring high to excessive maintenance have been recapped. In addition, no reconstruction has been proposed as a rehabilitative strategy because of the high cost.

Table 4

General Guideline for Interpreting the Results of Pavement Evaluation

Rank Number	Maintenance Level Required for Safe Operating Conditions
85 and above	Minimal
80 to 84	Some
70 to 79	Routine
60 to 69	Increased
40 to 59	High
10 to 39	Excessive to Prohibitive

The paved streets program provides for routine patrol (inspection) repair and maintenance of streets and lanes. During 1977 to 1981, prior to the implementation of the recapping program, the maintenance program for paved streets increased 70 percent over inflation (12 percent/annum inflation). The first five years following the initiation of the recapping program (1982 to 1986) the maintenance program increased by 18 percent over inflation (10 percent/annum inflation). From 1986 till 1988 the maintenance program increased 3.6% over inflation (4% per annum inflation). See Figure 2.

Our 5-year goal for pavement evaluation is to develop the most suitable pavement rehabilitation program for the 5-to 15-year period.

Table 5 shows the lane - km of roadway for each roadway classification that fall into each of the above ranges. Since we do not currently have any estimate of the rate of deterioration of the pavement structures, we cannot estimate the amount of additional roadway that will require rehabilitation during this period.

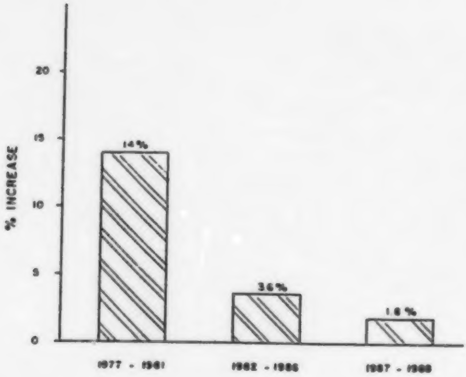


FIGURE 2: Paved Street Maintenance, Percent Increase Per Annum.

Table 5

Roadway Classification (lane-km)

	Ranking						
Roadway Type	**Below 40**	**40-49**	**50-59**	**60-69**	**70-79**	**80-84**	**85-100**
Expressway	0	10.4	7.9	27.2	28.3	35.8	5.1
Arterials	21.7	65.8	116.2	137.6	88.6	29.5	11.1
Collectors	35.8	116	150.5	79.1	42	2.1	3.2
Local	0	0	35.7	48.1	5.7	0	0

See Figures 3 and 4.

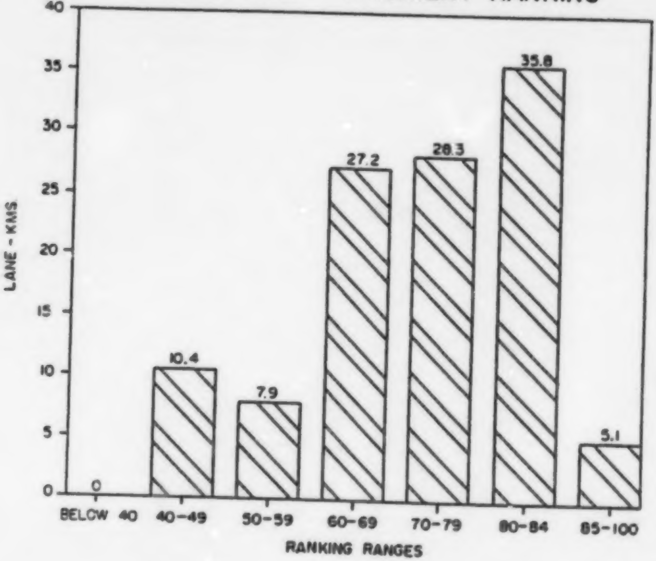
The loss reduction in roadways can be summarized as follows:

a) decreasing increase in maintenance cost,

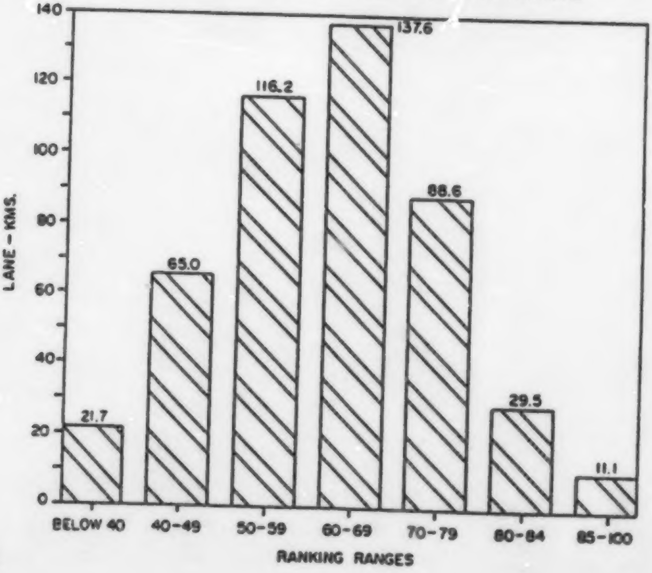
b) improved road surface in program areas, and

c) more effective planning for recapping and rehabilitation based on ranking.

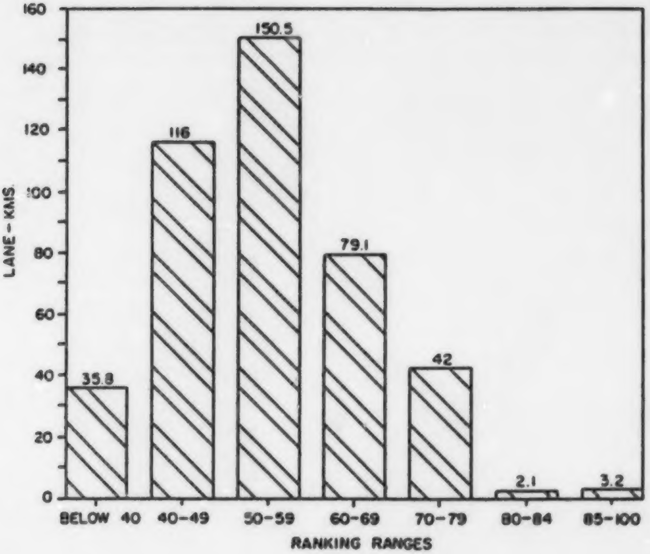
EXPRESSWAY - PAVEMENT RANKING



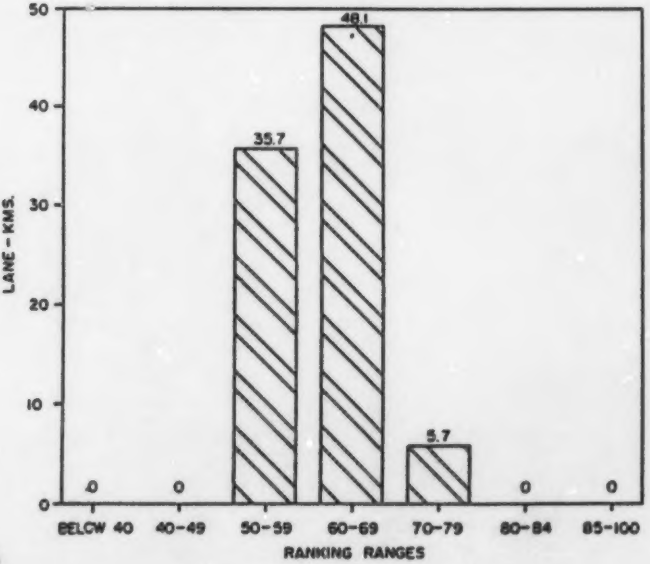
ARTERIALS - PAVEMENT RANKING



GRAPH 3



COLLECTORS - PAVEMENT RANKING



HIGH VOLUME LOCALS

GRAPH 4

1989 PROGRAM

In 1988, the Administration identified the need for a major thrust toward establishing a program of rehabilitating the City's infrastructure.

The proposals put forth by the Administration are, in some cases, the continuation of recently developed infrastructure programs, e.g., street recapping and street rehabilitation; and in other cases, a major addition to the replacement of "non-visual" services, i.e., storm sewer, watermains, and sewer mains. This program identifies areas of immediate concern but addresses neither the magnitude of the infrastructure problem nor the cost associated to resolve that problem in the long term. It is proposed that the Engineering Department develop a comprehensive plan for rehabilitation and maintenance - a plan which will also identify the long-term financial implications to meet the identified needs.

In addition to the specific projects approved for 1989 (see Appendix 4), the City has recognized a continuing need to review the adequacy of current practices, programs, and systems. In light of the future expansion of rehabilitation needs, it is proposed to increase activity in this area to ensure that all programs will be carried out efficiently and cost-effectively. In this regard the Engineering Department was given approval to conduct a future growth study in conjunction with two existing study projects. The original scope of these projects will be covered in the context of the overall program, including the additional $150,000 provided to review the paving programs.

FINANCING PROGRAM

Utilities

Existing capital and replacement programs address only the cost of constructing/replacing equipment required to operate the services and surrounding structures and the cost of reservoirs and the mains connecting the reservoirs to the plant. These reserves are not intended to fund the replacement of trunks and local networks. The utility operating programs do, however, cover the cost to maintain such systems.

It is anticipated that the current local improvement program will have to continue well into the future and likely escalate.

Because of the ongoing nature of the need to replace mains, it is recommended that the utilities' share of the cost not form part of the local improvement debenture borrowing. Instead, this share should be paid out of an annual provision for infrastructure repair provided in the utilities budget. In response to this need, an infrastructure levy for residential and commercial meters has been approved. The levy will be scaled from no charge to minimum residential usage of up to $50/month for heavy commercial users (see Appendix 2 for details). Appendix 3 provides a comparison of rates with other major prairie centres before and after the application of a surcharge. This levy is shown as an addition to the sewage rates for convenience only but will be reflected as a separate surcharge item on the utility bill.

In addition, an approved policy revision allows the transfer of any water utility surplus to a new infrastructure replacement reserve.

Warranty Financing

As part of the land development program, a warranty has been included in the prepaid rates. The purpose is to repair deficiencies and failures in the first 5 years following construction. Private developers are charged $15 per front metre to ensure areas for which the City assumes responsibility can be maintained during the first 5 years. The warranty charge is included in the prepaid servicing rates charged by the City to purchases of city-developed land. The warranty covers watermains, sewer mains, sidewalks, and roads.

Non-Utility Infrastructure Replacement

The City has recognized problems associated with the infrastructure as it relates to paved streets and has established a program of recapping and rehabilitation by providing a levy of 2 mills for this purpose. The Administration reaffirms its position that, where applicable, the user-pay philosophy should continue, either through normal local improvement charges or area charges. It is also clear, however, that some projects identified for reconstruction do not qualify for local improvement charges, i.e., City's share of storm sewers, sidewalk replacement, lane rehabilitation. With an expansion of an infrastructure replacement program, it may not be appropriate to continue the past practice of financing the City's share of local improvements by creating debt and charging such repayment to the mill rate. If the City acknowledges the need for a planned infrastructure replacement program, it would be appropriate to pay for its share of such replacement immediately in the year of planned construction as a special operating budget transfer to the capital budget for infrastructure replacement. For 1989, it is recommended that this transfer equal 1 mill.

The ultimate financial impact of the infrastructure replacement program will not be known until the Engineering Department has developed a comprehensive plan for rehabilitation some time late in 1989 or early 1990. However, by taking appropriate steps in the 1989 operating and capital budgets, it is anticipated that the City will have taken a major step toward financing a replacement program.

Infrastructure Reserve

City council approved the creation of an infrastructure replacement reserve, which for 1989 will be funded:

Budget Item	Funding for Infrastructure Replacement Reserve
General	Provision of 1 mill in the 1989 operating budget (Appendix 1)
Water/sewage Utility	Introduction, effective January 1, 1989, of an infrastructure surcharge (Appendix 3)
Water utility	An amount equal to the 1988 surplus (if any)

SUMMARY

The City of Saskatoon has implemented an infrastructure rehabilitation program which will reduce the deterioration of the city systems. At the same time, a study has been initiated to ensure rehabilitation is effectively planned so that all visual and non-visual services are repaired cost-effectively. The implementation of the ongoing utility surcharge to fund the infrastructure replacement reserve will ensure that a stable level of funds will be available to fund rehabilitation projects.

Appendix 1

Project	Estimated Cost	Property Share	City Share	Infra-structure Reserve	Prepaid Service
Sanitary Sewer Rehabilitation - Lorne Ave. Trunk	2,000,000			1,900,000	100,000
- Other Trunks/ Collectors	1,330,700	431,300		899,400	
Storm Sewer Rehabilitation - 14 St. Trunk	1,200,000	800,000	400,000		
Watermain Replacement	1,210,000	375,730		834,270	
Paved Streets	2,800,000		2,300,000		500,000
Sidewalks and Curbs	500,000	400,000	100,000		
Lane Rehabilitation	150,000		150,000		
Medians	100,000		100,000		
Future Growth Study	100,000				100,000
Bridges and Overpasses	200,000		200,000		
TOTAL	9,590,700	2,007,030	3,250,000	3,633,670	700,000
Existing Infrastructure Funding From Taxation			2,150,000 (2 mills)		
Additional 1989 Requirements			1,100,000 (1 mill)		

Appendix 2

LOOK AT YOUR BILL

THERE'S A NEW CHARGE

—City of—
Saskatoon

NEW CHARGE TO ALL CUSTOMERS OF CITY WATER / SEWER SERVICE

Residential Monthly Utility Bills	**Charge Per Meter**	**Commercial Utility Bill Month Water Usage (Cu. Ft.)**	**Charge Per Meter**
$0.00 - 4.99	Nil	0 - 4,999	$ 4.00 / Month
5.00 - 9.99	$2.00 / Month	5,000 - 49,999	12.00 / Month
Over - 10.00	$4.00 / Month	50,000 - 99,999	18.00 / Month
		Over - 99,999	50.00 / Month

APPENDIX 3

COMPARISON OF 1988 WATER & SEWER RATES

	Saskatoon Current		* Saskatoon Proposed		Regina		Edmonton		Calgary	
	Water	Sewer	Water	Sewer	Water	Sewer	Water	Sewer	Water	Sewer
Average Private Water User										
Winter 1400 cu.ft.	$15.46	$ 8.50	$15.46	$12.50	$19.18	$18.55	$32.98	$16.20	$10.03	$ 7.14
Summer 1700 cu.ft.	$18.13	$ 9.97	$18.13	$13.97	$23.34	$18.55	$39.25	$19.23	$10.03	$ 7.14
Fall 900 cu.ft.	$10.41	$ 5.73	$10.41	$ 9.73	$12.26	$18.55	$22.53	$11.17	$10.03	$ 7.14
Large Private Water User										
Winter 1600 cu.ft.	$17.24	$ 9.48	$17.24	$13.48	$21.95	$21.28	$37.16	$18.22	$10.03	$ 7.14
Summer 3800 cu.ft.	$36.82	$20.25	$36.82	$24.25	$52.41	$21.28	$83.11	$40.38	$10.03	$ 7.14
Fall 1300 cu.ft.	$14.57	$ 8.01	$14.57	$12.01	$17.80	$21.28	$30.89	$15.20	$10.03	$ 7.14
Large Industrial Water User										
Winter 1001800 cu.ft.	$ 9,428	$ 7,356	$ 9,428	$ 7,406	$13,868	$13,649	$14,628	$10,040	$ 7,486	$ 5,330
Summer 838200 cu.ft.	$ 7,888	$ 6,138	$ 7,888	$ 6,156	$11,603	$13,649	$12,628	$ 7,860	$ 6,295	$ 4,482
Fall 1193100 cu.f.t	$11,228	$ 8,737	$11,228	$ 8,787	$16,516	$13,649	$16,966	$10,795	$ 8,878	$ 6,321

* Saskatoon Proposed Water & Sewer Rates include a proposed Surcharge of up to $4 per meter per month to Residential Customers and a scaled Surcharge of up to $50 per meter per month to Commercial/Industrial Customers for Infrastructure Replacement Reserve.

Appendix 4

For 1989 the following program has been approved with two considerations to be noted:

1. The proposals for established programs, sidewalks and curbs excepted, are continuations of those programs at current levels, more or less.
2. The proposals for new programs are focused on high-priority, high-urgency projects involving significant risk in flooding and sewer backup.

A. Sanitary Sewer Rehabilitation

1.	Lorne Avenue trunk, Taylor Street to 8th Street, including replacement of the watermain.	$2,000,000
2.	4th Avenue local, 24th Street to 25th Street replacement including watermain reconnects	108,000
3.	108th Street local, Egbert Avenue to Central Avenue (including water main replacement which has been approved L.I.P., but cost savings will be realized if replaced together)	297,000
4.	Edward Avenue local, 33rd Street to Windsor Street, replacement including water main	404,250
5.	Avenue I local, 11th Street to Dudley Street lining	81,200
6.	Lane behind King Street and Spadina Crescent local, Duke Street to CPR lining	121,800
7.	13th Street collector, Albert Avenue to Lansdowne Avenue	97,000
8.	23rd Street collector, Avenue C to Avenue D	48,500
9.	Taylor Street trunk, Wiggins Avenue to Cumberland Avenue	173,000
	Total	$3,331,000

B. Storm Sewer Rehabilitation

14th Street trunk, Cumberland Avenue to river, replacement of lining	$1,200,000

C. Watermain Replacement

The proposal for 1989 LIP Watermains will be $1.2 million.

D. Paved Street Management

The proposal for 1989 paved-street management funded from taxation will be increased by $150,000 in 1989 to review the adequacy of this program. We propose to continue our $500,000/year program of pavement restoration funded from prepaid services warranty levies for 1989.

E. Sidewalks and Curbs

The engineering department proposes to greatly expand its 1989 LIP for sidewalk and curb replacement to $510,000. In addition, we propose a $50,000 program of filling longitudinal cracks in sidewalks, a problem that has plagued us recently.

F. Lane Rehabilitation

The engineering department is proposing a continuation of the $100,00 program for rehabilitating gravelled lanes and a new $50,000 program for rehabilitating paved lanes starting in the Central Business District.

G. Bridges and Overpasses

Our program of inspection will continue in 1989. Permanent repairs are required to the pedestrian overpass at the south end of the Traffic Bridge over the Saskatchewan Crescent interchange. The estimated cost for 1989 is $200,000.

H. Centre Median Rehabilitation

The Parks Department proposes to undertake a program of centre median rehabilitation beginning with a $100,000 program in 1989 for 22nd Street, from Circle Drive east.

SETTING RESEARCH PRIORITIES AND PERSPECTIVES FOR URBAN INFRASTRUCTURE PLANNING

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ABSTRACT

Environmental behaviour theory offers some insight, because it shows that people not only define values as changes from a reference point where loss values outweigh gain values but also evaluate their situation in separate dimensions, or compartments. Hence, for infrastructure planning to elicit urban residents' preferences and manage changes to meet residents' needs, research must be conducted to

a) identify residents' reference points;

b) determine tradeoff possibilities between gains and losses in different dimensions;

c) test process and product variables that will enhance resident tolerance to change; and

d) identify suitable combinations of product optimality and process optimality.

RÉSUMÉ

La théorie du comportement environnemental nous éclaire en ce sens qu'elle démontre que les gens non seulement établissent leurs valuers en tant que changements perçus à partir d'un point de repère où les pertes l'emportent sur les gains, mais évaluent aussi leur situation en dimensions ou compartiments distincts. Ainsi, pour que la planification des infrastructures réussisse à mettre à jour les préférences des résidents des villes et à gérer les changements de façon à répondre à leurs besoins, faudra-t-il mener des recherches pour :

a) relever les points de repère des résidents;

b) établir les compromis entre les gains et les pertes de dimensions différentes;

c) éprouver le procédé et les variables qui rehausseront la tolérance des résidents au changement; et

d) caractériser des combinaisons optimales de produits et de procédés.

INTRODUCTION

Urban infrastructure renewal programs provide a unique opportunity to (1) re-evaluate urban planning and engineering priorities in the 1980s and 1990s and (2) to adapt them to the needs and preferences of urban residents today, particularly with regard to the concern for urban environmental quality.

Because of the cost constraints, adapting infrastructure to meet residents' priorities requires that residents' preferences be identified so that gains and losses relative to the present situation can be traded off. In other words, infrastructure systems must become more cost-effective in order to provide more appropriate urban services, yet avoid excessive tax increases.

OVERVIEW OF ISSUES FOR INFRASTRUCTURE PLANNING

Five general research needs in infrastructure planning have been identified (Grigg, 1985):

1. decision-making and management processes in institutions on all levels of government and in utility companies, including capital budgeting and expenditures, and operation and maintenance management;
2. financing of infrastructure systems to improve effectiveness and equity in capital investment maintenance and operations;
3. infrastructure technology and materials to operate, measure performance, predict failures, replace older materials, increase reliability, locate problems and extend the life of existing systems;
4. infrastructure performance levels determined by professional codes, health standards, emission levels, nuisance bylaws, and departmental policies;
5. patterns of urban lifestyle resulting in residents' needs and expectations for health, environmental quality, convenience, and costs.

These research areas are elements in a system that delivers infrastructure services to urban residents (see Figure 1). Public works management administers financial means to build and operate infrastructure technology. The hardware must meet certain performance criteria that are meant to reflect the needs and expectations of urban residents. The elements are further linked by reporting protocols (see Figure 1):

- government regulators monitor emission values and observance of codes and standards and can require changes of the system to meet set values;
- residents' expectations and needs are reflected through political representation in budget decisions and management policy for the public works; and
- engineering management, and economic and planning sciences aim to elicit future urban patterns and lifestyles, and translate the resulting needs and priorities into effective management, financial, technological, and regulatory methods to infrastructure delivery.

Large-scale renewal programs especially offer the possibility to establish new priorities, reassess needs, and determine appropriate criteria for the next phase of infrastructure planning. This paper, therefore, focuses on the last two elements in the infrastructure planning: the regulatory research needed to determine residents' needs and then their translation into criteria.

ELICITING PREFERENCES AND MANAGING CHANGE FOR INFRASTRUCTURE PLANNING

Theory

Changes due to adaptation consist of losses and gains from existing levels of physical (quality, quantity), economic (impact of taxes, property values), social (community image and coherence), and political (community control and fairness) dimensions.

Since change often causes resistance among affected residents, infrastructure planning research must address the methodology basic to identifying opportunities and managing the changes in such a way as to gain acceptance.

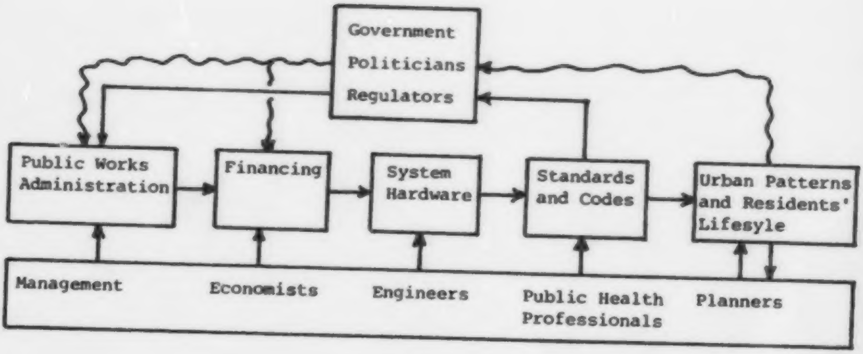
Government
Politicians
Regulators
Public Works Administration
Financing
System Hardware
Standards and Codes
Urban Patterns and Residents' Lifesyle
Management
Economists
Engineers
Public Health Professionals
Planners

FIGURE 1: Urban Infrastructure System.

Recent research in environmental psychology and economics provide us with the prospect theory (Kahnemann and Tversky, 1979, 1984) which embodies premises on which to base infrastructure planning research.

The prospect theory states, first, that changes are evaluated as differences relative to a reference point (see Figure 2) and that the absolute value of losses (relative to a reference point) exceeds the value of gains, i.e., losing $10 is considered more negative than finding $10 is considered positive. Then, people exhibit a strong preference to regain their original reference point, i.e., breakeven after an initial loss (Thaler and Johnsen, 1986). Finally, evidence (Kahnemann and Tversky, 1984; Thaler 1985) shows that decision-makers tend to compartmentalize "goods" in categories and thus separate different dimensions that make up their "wealth" into such attributes as "house", "food", "entertainment", and "environmental quality", for example. Among the numerous attributes that make up residents' quality of life are attributes that are affected by urban infrastructure systems.

Prospect theory has the following implications on residents' adaptation to changes in the infrastructure:

1. Residents' reference points are important benchmarks for their judgments of changes.

2. Losses weigh more heavily than gains relative to reference points. Because changes consist of gains and losses, some resistance is always likely to arise. Resistance to change is influenced by the type, magnitude, and process of change.

   For all types of losses, the asymmetrical value curve indicates that in-kind loss reduction is superior to compensation through alternative benefits (Zeiss and Atwater, 1987; Zeiss, 1988).

3. Tradeoffs of losses and gains for different dimensions are not easily and intuitively made by residents because of the tendency to compartmentalize values.

4. Residents' tolerance for change and, equally importantly, the factors that influence how much change residents will tolerate must be identified. Tolerance may be affected by the process through which the change is carried out.

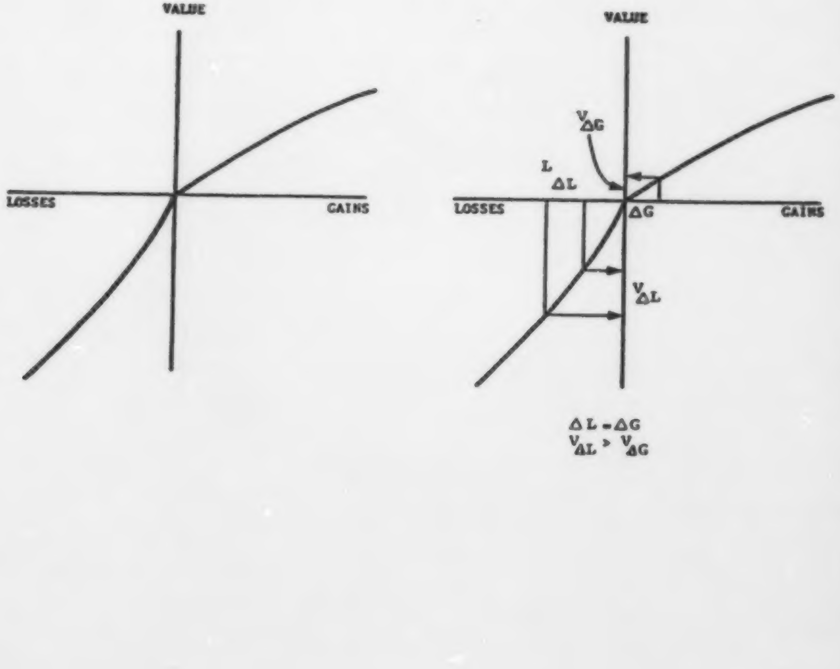
VALUE
LOSSES
GAINS
VALUE
V ΔG
L
ΔL
LOSSES
ΔG
GAINS
V ΔL
ΔL = ΔG
V ΔL > V ΔG

Figure 2. Prospect Theory Value Curve
Source: Kahnemann and Tversky, 1979

RESEARCH PERSPECTIVES

Reference Point Determination

The reference point is the level by which changes are compared to determine the value of the change, i.e., whether they constitute gains or losses.

Although the reference point is a simple concept, measuring it may be difficult. Different attributes, or dimensions, may have different reference points, hence an individual set of reference points may have to be identified for each type of infrastructure service or environmental quality dimension. The status quo is nevertheless a likely candidate for the reference point (Kahnemann and Tversky, 1979), however, it may be influenced by a variety of factors, such as:

- expectations of residents, e.g., that environmental quality could be better, resulting in the perception of the present condition as constituting a loss;
- past experience with infrastructure services and environmental quality elsewhere;
- recent shifts in needs or awareness of problems; e.g., the increasing concern for environmental quality, or unexpected events that generate such concerns as chemical spills, water treatment system failure, groundwater contamination, etc.; and
- comparison with similar or close neighborhoods.

The weight of these factors will be determined by having respondents in various communities evaluate a series of scenarios to determine their reference points.

Tradeoff Possibilities

After an initial loss (e.g., through a change) on one or a set of quality dimensions, the most preferred remedy has been shown to be an in-kind reduction rather than compensation through alternate benefits (Zeiss, 1988). This characteristic behaviour is probably due to compartmentalization of value dimensions, such as air and water quality, convenience, etc. To systematically test possibilities for tradeoffs, other benefits will be offered in sequences that vary the similarity of the value dimension. For example, the following sequence tests tradeoffs for an initial loss in water quality (see Table 1).

With increasing difference in the type of offsetting value, the tradeoffs become predictably less acceptable. Conversely, however, if the initial loss in money, through tax increases to provide infrastructure or enhance environmental quality, for example, is seen as a necessary "cost," then an alternate "good", particularly if seen as a necessary infrastructure or environmental quality dimension, will be considered fair (see Kahnemann et al., 1986).

For an initial loss of a quality dimension, the potential for tradeoffs can be predicted to decrease for unrelated offsetting benefits. This is not likely to happen for initial money costs for necessary infrastructure. Thus, a value asymmetry may limit tradeoffs for initial changes to intangibles.

Tolerance for Change

How much change will be tolerated and how can the change be managed to increase tolerance levels and facilitate adaptation?

It has been found that non-technical, social, and political factors affect change acceptance (Zeiss, 1988). Therefore, instead of defining change and remedies with technical measures, change tolerance will be tested for remedy levels that are defined in socially meaningful categories. For different types of changes and participation scenarios, various types response categories will be tested (see Table 2).

In the process of adapting to changes, a sequence of reactions may ensue, e.g., disbelief, anger, bargaining, depression, and, finally, acceptance (Kubler-Ross, 1969). The various remedies will probably affect the stages of residents' adaptation differently.

Process versus Product Optimality

Change management conventionally focused on achieving or maintaining certain physical results or quality levels under economic constraints. The scale for determining the best option is thus efficiency or cost-effectiveness. In contrast, change adaptation may be enhanced by allowing residents the choice to determine acceptable levels. Thus, elements of self-control may outweigh technical excellence in determining acceptable solutions (see Figure 3). In the context of hazardous waste facilities, Elliott (1984) generated empirical results that support residents' preference for participatory control over technical excellence. Furthermore, residents may actually be more frugal if guided by their own process of making a choice.

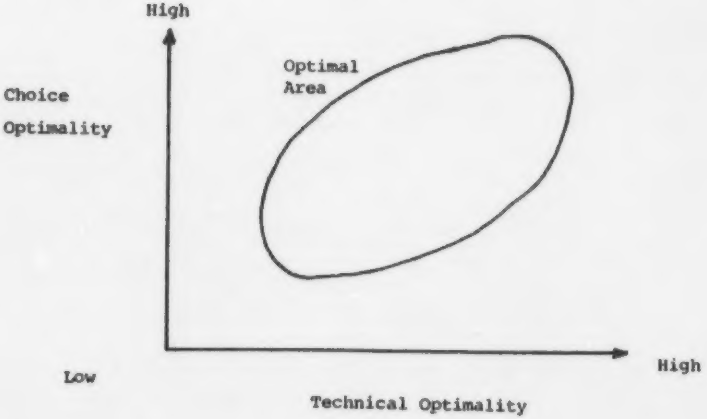
High
Optimal
Area
Choice
Optimality
High
Low
Technical Optimality

Figure 3. Process versus Product Optimality

SUMMARY AND CONCLUSIONS

Planning of urban infrastructure systems comprises five elements: infrastructure management, financing, technology development, performance level, and urban pattern identification. Due to the interconnections between elements and the overlap of professional fields, research in infrastructure planning requires interdisciplinary approaches.

Since infrastructure renewal provides a unique opportunity to adjust and balance service levels with costs and urban environmental quality, this paper focuses on the potential for research in identifying urban residents' priorities and needs which reflect urban lifestyle patterns and which can be translated into performance standards and criteria.

Infrastructure planning may result in changes that can be separated into combinations of gains and losses from a reference point. Since losses weigh more heavily than gains, people generally tend to resist change. Therefore, to introduce changes in infrastructure, the following research issues have been identified:

- location of residents' reference points;
- criteria for tradeoffs among change dimensions;
- tolerance for change and product and process factors that influence acceptable change levels; and
- preference between technical optimality and choice optimality.

Through research to elicit resident preferences, some methods of managing change have been revealed that can be tested. It is useful and necessary to conduct this research in the context of urban infrastructure systems, because they combine technical sub-systems (infrastructure hardware) with human sub-systems (cities, communities and households).

Thus, on a more basic level, infrastructure planning research constitutes an element of managing technical change in our society.

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Table 1: Tradeoff Possibility Testing

Initial Loss	Alternate Benefits	Compensating Dimension
Decrease in Quality of Water through additional discharge	1. Increase in water quality through reduction of a different discharge	environmental: water quality
	2. Increase in water enhanced treatment	environmental: water quality
	3. Increase in air quality equivalent to health risk posed by initial risk	environmental: air quality
	4. Reduction of traffic (noise, odour, etc.)	environmental: nuisance
	5. Construction of community recreation center	recreational: amenity
	6. Property value guarantees	monetary value
	7. Reduction in costs	monetary value

Table 2: Change Tolerance Tests for Different Response Categories

Change

- Type
- Infrastructure service
- Environmental quality
- Tax or cost level

Process

- Owner/operator controlled
- Resident participation
- Resident controlled

Response Categories

- Technical priorities and cost constraints dominate
- Residents concerns are acknowledged and preventive rationale is followed to address them
- Proponents address all major concerns according to preventive rationale to their best technical capability

A STRATEGIC APPROACH TO THE PLANNING OF URBAN INFRASTRUCTURE

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ABSTRACT

The City of Ottawa has recently produced an infrastructure management strategy to position it to meet its needs for the next 20- to 30-year period. Although the strategy was prepared by the office of the chief administrative officer, several City departments collaborated in its development. The document is divided into four main strategic areas: provision of services, financing the work, coordination with the regional government, and public awareness. It contains implementation plans for each strategy statement and action plans for the areas of human, equipment, and financial resources. Although the City must double the work it presently undertakes, a realistic, phased-in financing and works program is being proposed. A combination of funding methods have been chosen to support the work: increasing the sewage service rate on the Regional water bill, increasing subdivision and redevelopment charges, increasing the infrastructure allocation in the capital budget, pursuing avenues for provincial and federal assistance, and a contingency option. It is expected that a combination of these methods will meet the City's future requirements.

RÉSUMÉ

La ville d'Ottawa vient d'adopter une stratégie de gestion des infrastructures pour être en mesure de satisfaire à ses besoins au cours des deux ou trois prochaines décennies. La stratégie a certes été élaborée par le bureau du Directeur général, mais plusieurs services municipaux y ont pris part. Le document se divise en quatre principaux secteurs stratégiques : la prestation de services, le financement des travaux, la coordination des

activités avec le palier de gouvernement régional, ainsi que la sensibilisation du public. Il comporte des plans de mise en oeuvre touchant chaque énoncé stratégique et des plans d'action dans les domaines des ressources humaines, de l'équipement et des finances. Même si la ville doit doubler les travaux auxquels elle se livre en ce moment, un programme réaliste et progressif de financement et de travaux y est proposé. Une combinaison de méthodes de financement a été retenue pour soutenir les travaux : relever le taux de service des eaux usées sur la facture d'eau de la municipalité régionale, augmenter les charges de lotissement et de réaménagement, augmenter l'affectation des infrastructures du budget des immobilisations, demander l'intervention financière des gouvernements fédéral et provincial, outre l'option pour imprévus. On s'attend à ce qu'une combinaison de ces méthodes réponde aux futurs besoins de la Ville.

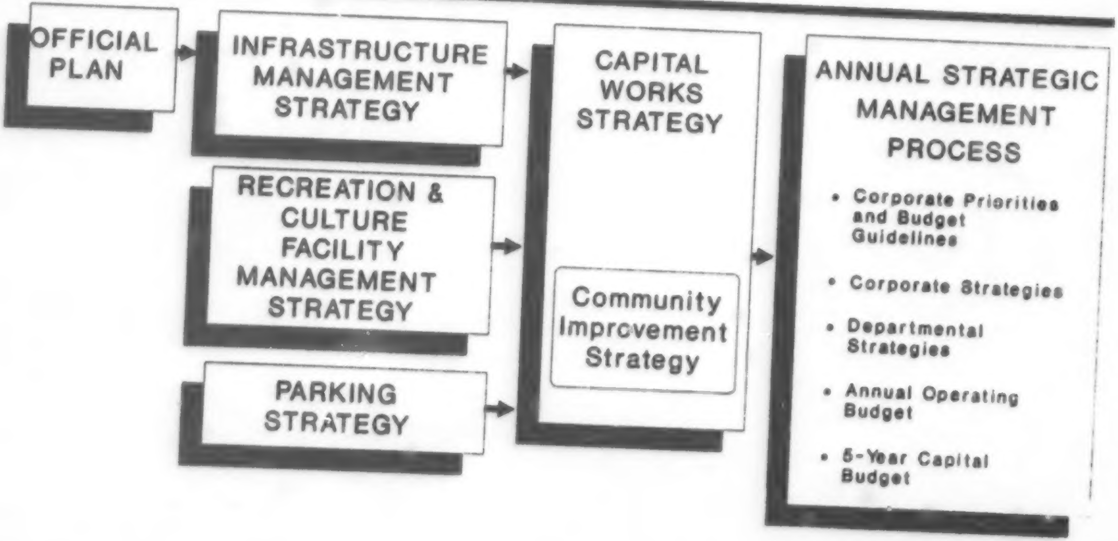
INTRODUCTION

Ottawa initiated its corporate planning process in 1984. The first year was devoted to an assessment of existing programs and the present and future issues they faced. In 1985, the present strategic management process was launched with the arrival of the City's chief administrative officer. The process has included an annual corporate planning and budgeting cycle and the preparation of long-term corporate strategies (Table 1). These will be linked with the City's proposed official plan and a major capital works strategy, both are expected to be completed in 1989. As an on-going refinement of the corporate planning and budgeting cycle, the City of Ottawa, in 1986, began to determine its corporate priorities with the assistance of the public. Economic development and housing were chosen as the two top priorities in that year. In the following year, concern shifted to the state of the city's sewers and roads, and City Council approved infrastructure (defined as roads, sewers, sidewalks, and streetlights) as one of its corporate priorities. As a result, an additional $4 million per year for the next 5 years were allocated for the rehabilitation of the city's deteriorating infrastructure, and an infrastructure management strategy was launched.

It was recognized at the time that this additional money might not be a sufficient increase to meet all future needs and that additional funds may be required. It was, however, considered a suitable initial increase while staff were undertaking the strategy. Subsequently, in response to an initial report, the Preliminary Report: Infrastructure Management Strategy, Council raised the additional $4 million for the infrastructure budget to $6 million to indicate its continuing concern for this area. This increased the allocation for infrastructure to a total of $17.4 million. Therefore, the last few years have

TABLE 1

LINKAGE BETWEEN THE INFRASTRUCTURE MANAGEMENT STRATEGY, OTHER MAJOR STRATEGIES AND THE CAPITAL WORKS STRATEGY



OFFICIAL PLAN
INFRASTRUCTURE MANAGEMENT STRATEGY
RECREATION & CULTURE FACILITY MANAGEMENT STRATEGY
PARKING STRATEGY
CAPITAL WORKS STRATEGY
Community Improvement Strategy
ANNUAL STRATEGIC MANAGEMENT PROCESS
• Corporate Priorities and Budget Guidelines
• Corporate Strategies
• Departmental Strategies
• Annual Operating Budget
• 5-Year Capital Budget

shown a significant change in the annual allocation from the $9 million level maintained between 1973 and 1986.

THE PROCESS

The Participants

Because infrastructure has been designated a corporate priority, the Corporate Planning Group in the office of the chief administrative officer spearheaded the infrastructure management strategy. Other departments, however, were closely involved - particularly the Department of Engineering and Works and the Department of Finance. The Departments of Planning and Development and the city clerk also participated at certain stages of the work.

At the beginning of the process, an infrastructure management committee, composed of members from the Departments of Engineering and Works, Finance, Planning and Development was established. After documents were reviewed by this committee, they were forwarded to a steering committee composed of the commissioners of the departments. Along the way, the membership was increased to include the commissioners of economic development and housing, so that these departments could be cognizant of the rationale behind the strategy and the resulting recommendation for an increase in development-related fees.

The Steps in the Process

This is the City's first effort at a long-term corporate strategy. It has appeared to be a success in terms of developing a coherent and defendable strategy and encouraging cooperation among departments. To accomplish the task, a strategic planning model was used. The steps in this model are reflected in the format of the strategy document. They are:

- Define the issues to be addressed. This will indicate the organization's strengths, weaknesses, opportunities, and threats in relation to these issues.

- Define the long-term goals and objectives.

- Consider alternative strategies and recommend the best combination of strategies and the implementation mechanisms to carry them out. Implementation mechanisms could include programs, procedures, development of more detailed strategies, etc.

- Recommend a set of action plans to assist the organization to put the strategies and implementation mechanisms in place. These cover the areas of human, equipment, and financial resources. In other cases, these might also include land or building resources.

- Develop performance indicators and evaluation mechanisms to monitor the progress of the strategy.

This model proved to be very successful in clearly taking us through the steps towards issue resolution. At the beginning of the exercise, needs estimated at $700 million seemed well beyond the City's funding capacity. At this point, it appears that an increase in the sewage service rate of approximately $50 per year for the average water user and an increase in subdivision and redevelopment charges to equal the growth-related capital costs will cover the annual bill and a solution is now within our grasp.

THE BACKGROUND

As with many other municipalities, much of the basic infrastructure in Ottawa was constructed during the 1950s and 1960s. Then, during the 1970s and early 1980s, the public turned its attention to other priorities both to further the quality of life in Ottawa and to address pressing social issues. This included financing such items as recreation programs and facilities, community services, and housing. Although these were very valid concerns, a result of the concentration on other priorities was that additional monies were not allocated for the repair and maintenance of the basic infrastructure. Consequently, the level of deterioration has worsened, and Ottawa must now begin to cover the large costs of bringing infrastructure services up to an acceptable level of maintenance.

THE STRATEGY

The infrastructure management strategy for the City of Ottawa is divided into four major areas: the provision of services; financing the work; cooperation with the Regional Municipality of Ottawa-Carleton; and public awareness. Each of these contains an overall approach and individual strategies and implementation plans. These are followed by detailed action plans for the areas of human, equipment, and financial resources, and a section on monitoring the strategies through performance indicators and evaluation mechanisms.

Provision of Infrastructure Services

Under provision of services, the individual strategies are divided into two phases. For the first 5 years, the major emphasis is upon further gathering, processing, and managing an information base which will position the City better in the use of such methods as life-cycle costing and forward planning. A number of short-term programs, such as interim stormwater management measures to alleviate basement floodings, repair and rehabilitation of bridges, and the conversion of all incandescent lighting to high-pressure sodium lighting, are also proposed. During this time, a long-term strategy for the repair and replacement of sewers, roads, sidewalks, and streetlights will gradually be phased in and then be the focus for the foreseeable future. This would include a program to separate the combined sewer system, dealing with sewer capacity issues through development-related charges, and increasing the use of life-cycle costing to determine the most cost-efficient timing of work on roads.

Information. Although considerable information about Ottawa's infrastructure has been collected, storage of such a large volume of statistics has been difficult. However, Ottawa has, at present, no effective means of either storing historical infrastructure information and analyzing the data and, therefore, is not in a position to systematically determine life-cycle costing of its resources. The development of a system for the bulk of the City's infrastructure is expected to take approximately 5 years to complete and 10 years for sewers, since much of the system must first be surveyed by CCTV. Ottawa will use the Provincial Sewer Inventory and Management System (SIMS) to model this sewer work; and for roads, the Province's Roads Inventory and Management System (RIMS). Once the systems are running, we will be able to input all information about maintenance and reconstruction work completed for a particular stretch of road, sewer, or sidewalk. Then, based on this information and histories for similar situations, it will be possible to identify when future work should be scheduled.

At this point, the estimate for our infrastructure reconstruction needs is approximately $30 million annually, which is an additional $13 million above the expected 1989 capital budget allocation. What we shall try to discover more precisely over the next 5 years is when this work must be completed to avoid major problems, and how, through such methods as life-cycle costing, we can reduce these estimated costs.

Sewers. Ottawa's sewer system, as a whole, works well during periods of dry weather; however, in wet weather, surcharging or overloading may occur. To alleviate basement flooding, which can occur when the system surcharges, numerous overflows were built over the years. These direct stormwater to the Rideau or Ottawa rivers. Unfortunately, at the same time, this has contributed to the closing of beaches along the Rideau and Ottawa rivers. At this point, most of the overflows to the Rideau River have been eliminated (only two remain), but there are 18 which empty into the Ottawa River.

Ottawa has three basic reasons for adding to or reconstructing its existing sewer system:

Physical Condition. The sewer system is breaking down because of age and other factors, such as the lack of capacity for existing development. This is primarily a problem with the combined sewer system, although it also affects some parts of the rest of the system. This is Ottawa's first priority in terms of capital budget financing.

Additional Capacity. Additional capacity would mainly be created by major development projects according to the growth strategy of the proposed official plan. The City should ensure that any updating of the system to increase capacity be supported through subdivision and redevelopment charges and that these be raised to a level at which the municipality can be adequately compensated.

Environmental Concerns. This pertains primarily to a systematic replacement of the combined sewer system although there are also environmental concerns related to the partially-separated system. Driving forces are the public concern for the pollution entering the Ottawa and Rideau rivers from overflows, the Province's enforcement of its environmental legislation, and the regional government pressing us to reduce the water content in sewage arriving at their expanded sewage treatment plant.

The Combined Sewer System. Much of Ottawa's combined sewer system, located in the central part of the city, is 80 to 100 years old and constructed of various materials including stone, brick, clay, and different classes of concrete. Because of its age, the system is nearing the end of its useful life-span.

If Ottawa had followed the course taken prior to making infrastructure a corporate priority, it would have provided funding to replace the combined system in about 50 to 60 years. Present indications tell us, however, that it is highly unlikely that it would have lasted long enough for the City to continue on this course. Therefore, a significant decision which Ottawa will have to make is whether to pursue an accelerated sewer replacement program of about 35 years based on correction of deteriorating pipe conditions (this is the condition option discussed in the next paragraph) or a systematic 20 year sewer replacement program based on environmental concerns (the environmental option). At this point, it is difficult to predict whether sufficient parts of the system will last for 35 years but it seems possible. There is, of course, an array of choices between these two major options, and the City could chose the one which best combines speed with its ability to finance the work.

Condition Option. Due to the high costs of sewer repair and replacement, the condition option represents the option which Ottawa can afford. Although the City is concerned about the quality of the environment, a faster replacement of the combined system and the deteriorating parts of the partially separated system seems beyond our funding capacity. The cost of this option would be approximately an additional $2.7 million per year for a total of $10.7 million annually. This choice would still, however, necessitate the allocation of additional funds to the infrastructure budget for sewers and would be based on the assumption that enough of the system could last until the entire system could be replaced at this slower pace.

Environmental Option. If the Province of Ontario or the regional government are not satisfied with the solution offered by the condition option because of high pollution levels in the rivers or excess water in the sewage sent, it may wish us to replace the combined system systematically in a shorter time frame of possibly 20 years. In this case, the initial annual cost of replacing the system would be considerably higher than if it were replaced gradually (approximately $7 million per year in addition to the present budget for sewers for a total of $15 million annually). Moreover, many of the recipients of the environmental benefits of the program reside outside of this municipality. Therefore, if this option seems preferable, it is suggested that we seek subsidies for the additional work from the regional government, the Province of Ontario, and possibly the adjacent municipalities which would benefit.

Roads. At the present time, there is a considerable inventory of roads requiring reconstruction because the budget for the road program increased very little between

1973 and 1986. Due to the high cost of the reconstruction work facing us and the fact that Ottawa attempts to combine its road and sewer work, we may need to complete this over 20 years, although it is assessed as a 10-year need.

To replace road assets as a result of depreciation, Ottawa should have annually undertaken reconstruction at a level equivalent to approximately 2 percent of the value of its assets. Assuming the value of its 743 km of roads to be in the order of $412 million, this would presently amount to a minimum of $8.2 million per year, not including maintenance. Maintenance for this level of depreciation is estimated to be in the order of $4 million annually. Given the fact that Ottawa has not historically directed this level of funding to roads, the "catch up" level is considerably higher than $12.2 million.

In terms of road replacement and repair, a major decision will be how quickly to proceed. This will affect the degree to which a shift to the use of life-cycle costing can be made. If money is not available, then the focus may have to remain on the relatively more costly overlaying of current and short-term needs. With increased funding, Ottawa can tackle the problem from both ends, by overlaying good roads at the appropriate time to maximize their life-span while continuing to maintain all roads at an acceptable level.

Sidewalks: New Construction and Reconstruction. Over the years, Ottawa has allocated proportionately more money to sidewalks relative to needs than it has for roads so that a program of preventive maintenance has been possible and the anticipated costs and extent of replacement are not nearly as daunting. We will therefore continue to replace sidewalks to alleviate current and short-term concerns for surface conditions and structural adequacy. If Ottawa wishes to catch up and maintain its sidewalks at an optimum level within a 10-year time span, it will require additional funding to bring the sidewalk reconstruction allocation to about $1.3 million.

The City presently allocates $220,000 annually for new sidewalks. Recent surveys indicate that over twice this amount will be needed. In addition to this work, Ottawa allocates $100,000 each year to provide ramps for handicapped persons. Specific locations are determined from requests from interest groups and this level of work appears to be adequate.

Sidewalks: Bridges. Until recently, Ottawa has had no major concerns with the maintenance of its bridges. These include light bridges: three of which are vehicle bridges and five, pedestrian bridges. As the City does not possess the expertise for this work, the regional government monitors them and consultants are hired to complete the repairs or rehabilitation. Four of the bridges (two vehicular and two pedestrian bridges) will require repairs within the next 5 years. We plan to complete this work quickly because the program is relatively small in terms of dollars and involves only four projects.

Streetlights. In 1979, Ottawa decided to give priority to the provision of streetlights for each unlit street. Consequently, it has undertaken an active program to install high-pressure sodium lighting along these streets. There are now approximately 140 unlit streets remaining and we expect that the installation program of streetlights there will be completed within 4 years. Staff previously proposed a program of converting the entire incandescent lighting system to high-pressure sodium because this type of lighting is considerably cheaper for the City to operate. However, in 1981, it was decided to defer a conversion program until the new lighting program has been completed or the pay-back period for conversion is less than 10 years. At this point, a straight conversion program of a high- pressure sodium unit for an incandescent unit has a pay-back period of 5 years. It is estimated that the pay-back period for Ottawa would be approximately 6 to 7 years because extra work would be required to replace brackets, wiring, and internal connections. Due to the anticipated cost-savings, an allocation for the conversion program is being recommended as a service improvement, and it is suggested that most of this program be completed relatively quickly. We have estimated that, upon completion, the annual cost-savings from conversion will be 47 percent of the energy supply portion of the operating budget, or 13 percent of the total annual operating budget for streetlights. The program would involve the replacement of approximately 5,300 lights on city streets. Once the new lighting and conversion programs have been completed, it is proposed that the City concentrate on upgrading its streetlighting system where required.

Financing the Work

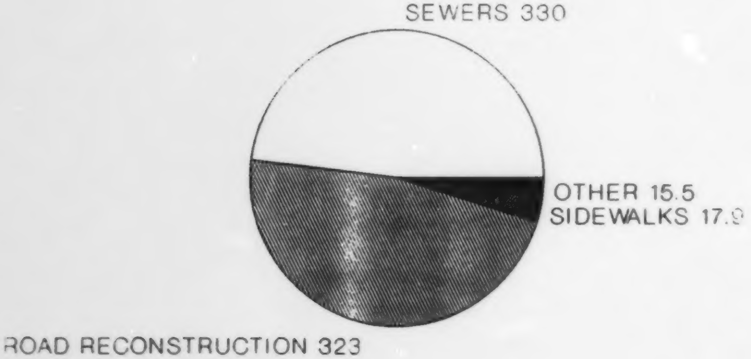
Estimate of Funding Required to Meet Needs. Ottawa has estimated its long-term infrastructure needs to be in the order of $700 million. This price tag is based upon present estimates for sewer replacement and road, sidewalk, and bridge reconstructions (Table 2). Ottawa's initiatives to introduce life-cycle costing for roads and its investigations into lower cost options to sewer replacement may lead to noticeable savings, thus reducing these figures. While it is recognized that the estimated dollars may seem large, Ottawa is faced with the fact of being a mature city with an old infrastructure.

TABLE 2

WHERE ARE WE NOW

Estimated Long-Term Needs

(Millions of Dollars)



SEWERS (330)
- separate combined sewer system (200)
- replace partially-separated sewers to remove storm water (100)
- replace sewers due to condition (30)

STREETLIGHTS (9.5)
- new (2)
- conversion (2.5)
- upgrade (5)

INFORMATION (1)

MINOR HARD SERVICES (5)

ROAD RECONSTRUCTION (323)

SIDEWALKS (17.9)
- new (4.5)
- reconstruction (12.9)
- handicapped (.5)

Physical assets naturally deteriorate over the years, particularly if they have not received the appropriate regular maintenance due to lack of funds. Ottawa has extensive assets (Table 3) valued roughly at $1.3 billion. Assuming a 1-percent depreciation rate for sewers, 2 percent for roads and sidewalks, and 3 percent for streetlights, this would require over $24 million per year to maintain. Therefore, the estimated needs reduced to an annual requirement of approximately $30 million (condition option) to $34 million (environmental option) appear reasonable considering the need to catch-up as a result of lack of sufficient funding in previous years.

It should be stressed that the figure of $700 million is for capital budget items only. There may also be large operating costs over the years as maintenance of assets will be increased to help reduce the need, or the frequency of need, for reconstruction. In addition, items such as additional staff, training of staff, and small equipment are operating budget items and are not included in the estimates. Therefore, while the capital budget estimates provide an indication of the magnitude of the problem, they do not at this stage provide a comprehensive overview.

Financing Options. The two largest costs facing the City are for sewer and road services. Together they constitute approximately 96 percent of the estimated costs of repairing and replacing existing assets. Therefore, the recommended financing strategies concentrate upon securing funding to finance this particular work.

Ottawa reviewed a considerable number of financing options but had to reject most for various reasons. Among those not considered suitable were: bond guarantees, development rights transfer to private industry, tax increment financing, local improvement charges, and sale and lease-back from private industry.

The methods which did have potential were few: increasing the sewage service rate on the water bill, increasing subdivision and redevelopment charges, increasing or reallocating funds in the capital budget, and seeking assistance from senior levels of government.

Sewage Service Rate. Ottawa's sewage service rate is extremely low. Citizens of Ottawa have the lowest water bills of any of the municipalities in this region. At 9.47 percent, revenues from the sewage service rate do not approach Ottawa's costs of maintaining and repairing its existing sewer system and the rate is considerably lower than the rates charged by the surrounding municipalities of Nepean, Kanata, and

TABLE 3

EXTENT OF ASSETS

• SEWERS		1,508 km
	- Combined	265
	- Sanitary	621
	- Storm	622
• ROADS		743 km
	- Collectors	184
	- Local	559
• SIDEWALKS		765 km
	- Concrete	394
	- Asphalt	367
	- Other	4
• STREETLIGHTS		20,516
	- Incandescent	5,924
	- High Pressure Sodium	10,509
	- Other	4,909

VALUE OF ASSETS

• SEWERS	$780 Million
• ROADS	$412 Million
• SIDEWALKS	$ 88 Million
• STREETLIGHTS	$ 32 Million

ANNUAL DEPRECIATION

• SEWERS	$ 8 Million
• ROADS	$ 9 Million
(Maintenance For This)	$ 4 Million
• SIDEWALKS	$ 2 Million
• STREETLIGHTS	$ 1 Million
TOTAL ANNUAL DEPRECIATION	$24 Million

Gloucester (presently at 60, 60, and 53 percent respectively), and the Region (at 100 percent). As we must begin to undertake the necessary work before it is too late and the costs are beyond our ability to absorb them, our charges must be brought up to an acceptable level to meet our expenditures. We have found that we can cover a program for the operation, maintenance, repair, and deferred maintenance of our sewer system through an increased sewage service rate which at 46.4 percent would still be below that of most surrounding municipalities. The main problem we face is that the present rate is so low that the proposed increase (36.93 percent) is difficult for our politicians to face. This may prove to be a stumbling block and may mean that we will take longer than expected to begin to get "our house in order".

Subdivision and Redevelopment Charges. Ottawa's subdivision and redevelopment charges are also extremely low. They have not been raised since 1974, a fact that has seen us forgo a substantial revenue source during the major building years. As Ottawa has very little land left for subdivisions, we do not expect to gain much from raising these fees, but there will still be considerable redevelopment. Therefore, it is hoped that City Council will accept our proposal to raise redevelopment charges to cover the actual costs of providing expanded sewer facilities to these projects. This would mean raising existing charges by about double their amount so, again this is a difficult recommendation to place before the political level - even though the fees would still be well below those of surrounding municipalities.

Capital Budget Reallocation. Although the capital budget allocation for infrastructure had been very low until 1986, city council has increased it substantially since then. With a considerable number of other demands on the capital budget over the foreseeable future, a further significant reallocation of dollars to infrastructure seems less promising.

The main intent of the infrastructure financing strategy for now is to establish an approximate capital budget funding level which would be adequate to begin to address needs before the problem becomes so serious that it is well beyond our ability to handle it. In addition, Ottawa will soon be undertaking a capital works strategy which will be looking at all of its long-term capital needs (over about a 20-year period). This will form a basis upon which we can set our overall strategic direction for major items. From this, each year, departments can then lay out their plans in their corporate and departmental strategies which are part of the City's annual corporate planning and budgeting cycle.

Pursuing Provincial and Federal Assistance. We are also proposing to pursue a variety of ways to encourage the provincial government to assist us with funding our infrastructure needs. The Province has responded favourably to the position put forward by the Federation of Canadian Municipalities, although this has not yet materialized in terms of subsidies. Ottawa shall continue its own efforts on a variety of fronts, including suggesting changes to some provincial programs. Assistance will be particularly important if the Province presses us to accelerate our proposed sewer program to address environmental concerns.

The federal government has been less positive about helping municipalities with their infrastructure problems, but we will continue to discuss our needs with this level of government as well. The federal government has assisted municipalities with infrastructure programs in the past through such efforts as the sewage treatment program (1961-74), the municipal infrastructure program (1975-78), and the community services contribution program (1979-80). An argument can be made that infrastructure built under these programs should also be upgraded by the federal government.

The Overall Financing Strategy. Ottawa's overall infrastructure financing strategy is geared to sustain an appropriate and sufficient level of annual funding to support the anticipated infrastructure work over time and to have the user pay. For sewer projects, in particular, the strategy is to cover the proposed sewer program through the sewage service rate and the subdivision and redevelopment charges.

Once the costs associated with the sewer system have been absorbed by the increases in the sewage service rate and the subdivision and redevelopment charges, this could free some of the present budget allocation to finance other infrastructure items, particularly for road work. It is anticipated that this approach could result in the entire infrastructure package of approximately $30 million per year being funded without a substantial increase in the present mill rates. If, however, city council decides not to follow the recommended strategy, then the additional work would have to be financed substantially from taxes. As Ottawa is close to its maximum debt level, that option would result in noticeable increases in the mill rate.

Phased-in Financing Program. As we must move from a $17.4 million program to a $30 million program, we cannot expect to do this in 1 year - regardless of the urgency of the need. The rationale for a phased-in financing program for the long-term sewer, road, sidewalk, and streetlighting allocations is that:

(a) our Department of Engineering and Works has insufficient resources to undertake a major increase in contracts until additional staff resources are in place. A phased-in program will give the department time to hire and train the appropriate staff to oversee this work.

(b) it will take several years for the information base on assets to be assembled so that it can provide a more accurate estimate of required work and costs.

(c) the construction industry requires lead-time in such areas as materials manufacturing, consulting, and construction contracts to respond adequately to this long-term increased demand;

(d) the provincial and federal governments may assist municipalities with their large infrastructure costs. Programs at other levels of government may take several years to develop. A phased-in program may make better use of funding available from these sources.

Utility Company. The financing section also includes a contingency strategy which could be considered, if the costs of repair and reconstruction are found to be much higher than those originally estimated and the City of Ottawa cannot meet the costs under the existing organizational structure.

Some municipalities in the United States, faced with similar or more serious problems of financing infrastructure renewal, have set up an independent authority with its own budget to address the infrastructure situation. The private sector equivalent to this is presently being initiated in Britain. This option, however, may cost the taxpayer more money than the present arrangement as it would add another level of administration.

Coordination with the Regional Government

It has become increasingly apparent that there is a need for Ottawa to address issues at a strategic level when they involve both coordination of works with the Regional Municipality of Ottawa-Carleton and matters which affect the environment of the area. Two broad issues are touched on here but, as we proceed with the implementation of the strategies, it is expected that other topics will be added to our discussions with the regional government and adjacent municipalities.

The long-term coordination between the City of Ottawa and the regional government is particularly important due to the interrelationship between the work of the two levels of government. In Ottawa, the regional government owns all major roads, collector sewers, watermains, and about half of the streetlights. This need for coordination to avoid situations where a street is excavated numerous times because one level of government has received funding for a project but the other level has yet to wait a year or two before it can fund its part of the project. It would, therefore, make a great deal of sense in the future, if the two levels of government could coordinate strategies and resulting projects for several years ahead of time, rather than doing this on an annual basis.

Public Awareness

Strategy Level. In the past, staff have alerted both city council and the public concerning the need to allocate additional dollars to infrastructure but these warnings have not been given the desired response. This has resulted partly from a proliferation of demands from other sectors, e.g., new parks, community centres, assisted housing, etc. Many of these demands appeared more immediate as people could see the effects of not having these facilities in their communities and were relatively less concerned with the upkeep of existing services, particularly those which are out of sight. As Ottawa had already built the majority of its basic infrastructure, the natural tendency was to concentrate upon those facilities which were not yet in place. Part of the problem has also been the difficulty the public has had in grappling with the figures presented to it. Without sophisticated equipment, which is now available, engineers were unable to present complete information and it was often not offered at a level at which the public could easily comprehend. The estimates for large costs for the future for all infrastructures often overwhelmed people. Therefore, a part of the infrastructure management strategy has been the preparation of a public relations package which "tells the story" in manageable terms.

Implementation Level. Ottawa will also focus on improving and increasing the program delivery of client services, thus enhancing public satisfaction with municipal infrastructure services and the resulting condition of city sewers, streets, sidewalks, bridges, and streetlights. At the individual project level, before repairs begin, we will provide specific information to the public affected, so that they understand why the work is needed and what it is intended to achieve; and we will set up a speedy concerns and complaints resolution system for any problems which arise in relation to the work.

We will distribute a follow-up questionnaire to citizens around a municipal job site to determine their satisfaction with the work performed in their area, collect and tabulate the data from questionnaires, and use this information to make any required improvements in the way in which work is completed. We will ensure that good contact is maintained with the media so that with being fully informed, they are sensitive to the issues and therefore do not unknowingly misrepresent the situation.

CONCLUSIONS

The infrastructure management strategy for the City of Ottawa recommends a program of maintaining, repairing, and replacing infrastructure services which will be very costly over the foreseeable future. The large costs are partially a result of the lack of consistent and adequate funding in the past. The costs of infrastructure rise exponentially when it is neglected. If we are to be fair to future generations, we must do our part to ensure that basic infrastructure is kept in good repair and replaced when necessary.

The work to maintain our infrastructure offers the community substantial benefits. The health and safety of citizens is the primary consideration in the development, maintenance, repair and replacement of infrastructure. Lack of an adequate sewer system can create significant environmental problems and dangerously affect the health of individuals. Lack of lighting can increase the incidence of crime and accidents. Poor roads can increase the rate of accidents as well as greatly slow the flow of goods and traffic. There is a direct relationship between the state of maintenance of roads and the costs of operating a vehicle "...poorly maintained street and road surfaces exact a high price for automobile owners".(1) Studies have shown that the costs to a driver of operating a vehicle on poor roads were about double the costs of driving on good roads.(2) Uneven sidewalks or the lack of sidewalks are a danger to all, but particularly the young and seniors.

The work to repair and replace infrastructure is labour-intensive and an excellent source of job creation, particularly in times of economic restraint. A well-maintained infrastructure is also an attraction to business. Most businesses rely upon the quick and safe movement of goods, and need to be assured that transportation systems are dependable. In addition, business people are interested in locating in a place which provides an attractive environment for their employees. A reputation for backed-up sewers and roads with potholes does not enhance a city's chances of attracting new business.

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(1) Cristofano, Sam M., Management of Local Public Works, I.C.M.A., p. 241.

(2) ibid p. 243

These are just a few indications of just how important a properly maintained infrastructure is to our modern society. We have had the luxury in the past of our infrastructure remaining in relatively good condition as we concentrated on the development of other services. However, much of our infrastructure is nearing the end of its useful life-span, unless we do something to extend it. It does not appear that Ottawa is too late to address the problem adequately. Therefore, it is expected that our infrastructure management strategy will meet the challenges ahead and ensure that Ottawa continues to provide an attractive, safe, and healthy environment for its citizens.

REFERENCE

Cristofano, S. M. and Foster, W. S. 1986. Management of Local Public Works, International City Management Association, Washington, D.C.

GROWTH MANAGEMENT AND THE TIMING OF URBAN INFRASTRUCTURE EXTENSIONS

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ABSTRACT

Faced with financial constraints, many Canadian urban centres are forced to balance the cost of opening up new growth areas with the need to maintain or replace older infrastructure. Prudently managing the timing of infrastructure extensions into new suburban areas can provide both an effective mechanism for implementing growth management policies and a means of lessening the demands on a municipality's capital budget, making more resources available to upgrade existing infrastructure.

This paper describes a practical tool which can place decision-makers in a strong position to effectively manage the timing of infrastructure extensions, both on a city-wide basis and in response to *ad hoc* development requests. The approach includes a concise policy base; an open forum for dialogue with the development industry and individual developers; and a current, comprehensive information base.

Calgary's recent "boom and bust" experience provides a realistic backdrop for describing the different management approaches used under rapid- and slow-growth conditions. This comparison serves to highlight the features of the strategy described in this paper and illustrate the direct relationship between growth management and the use and timing of municipal infrastructure.

RÉSUMÉ

Confrontés à des restrictions financières, de nombreux centres urbains du pays se retrouvent contraints de compenser le coût d'aménagement de nouveaux secteurs de croissance par le besoin de maintenir ou de remplacer les vielles infrastructures. Synchroniser, grâce à une gestion prudente, le prolongement des infrastructures jusque dans les nouvelles banlieues, peut s'avérer à la fois un mécanisme efficace de gestion de la croissance, et un moyen d'atténuer la demande de prélèvements sur le budget des

immobilisations de la municipalité, rendant accessibles davantage de ressources pour améliorer les infrastructures déjà en place.

L'exposé décrit un outil pratique qui peut mettre les décideurs dans une position de force pour gérer efficacement le moment de prolonger les infrastructures, tant à l'échelle de la municipalité qu'à la suite de demandes particulières d'aménagement. L'approche comporte des principes de base concis, un forum libre favorisant le dialogue avec l'industrie de l'aménagement et les promoteurs, de même qu'une base d'information complète, à jour.

La situation percutante qu'a connue récemment Calgary expose, en guise de toile de fond, les différents modes de gestion employés selon une croissance rapide ou lente. La comparaison met en lumière les traits dominants de la stratégie décrite dans l'exposé et illustre la relation directe existant entre la gestion de l'expansion et l'utilisation et la synchronisation des infrastructures municipales.

INTRODUCTION

Calgary's economy has long been recognized as having something of a "boom and bust" character. Although that image has probably been romanticized somewhat for many decades, the hard reality of rapid growth in the 1970s, followed by sudden population losses in the early 1980s, has forced the City to re-examine the way in which growth and city expenditures, can best be managed under very different conditions.

To understand the growth management strategy now in place in Calgary, one needs to appreciate how growth was accommodated and serviced during the rapid-growth years. This comparison illustrates the extent to which the City's objectives and policies have been challenged to deal with slow growth. It also demonstrates how today's strategy can place the city in a stronger position to manage periods of rapid growth, if and when they return.

INFRASTRUCTURE EXTENSIONS TO SERVICE HIGH-GROWTH PERIODS

As Figure 1 illustrates, Calgary's growth was very rapid during the mid-1970s, with the population growing by an average of about 17,000 people a year. Faced with increasing housing demands and rising house prices, the City adopted a growth management policy of "simultaneous growth in all directions". Simply put, the City endeavoured to extend services - at the developers' request - in all directions, as demand was expressed in the marketplace (see Figure 2). The City was subdividing and servicing an average of 1,600 acres a year over this period (see Figure 3) - a strong and sustained level of demand.

The extension of major utility infrastructure (e.g., storm and sanitary sewer trunks, and watermains) were constructed at the outset by the City or by its related utilities. Cost recovery systems were in place which enabled the City to recoup the capital and financing costs on a per-acre basis as development proceeded in each service area.

The costs of on-site servicing and connections to the major City facilities were borne directly by each developer, as were the costs of local and collector roadways. The City, with the aid of provincial cost-sharing programs, constructed expressways, interchanges, and transit facilities.

FIGURE 1

CITY OF CALGARY
ANNUAL POPULATION CHANGE
1970 - 1988

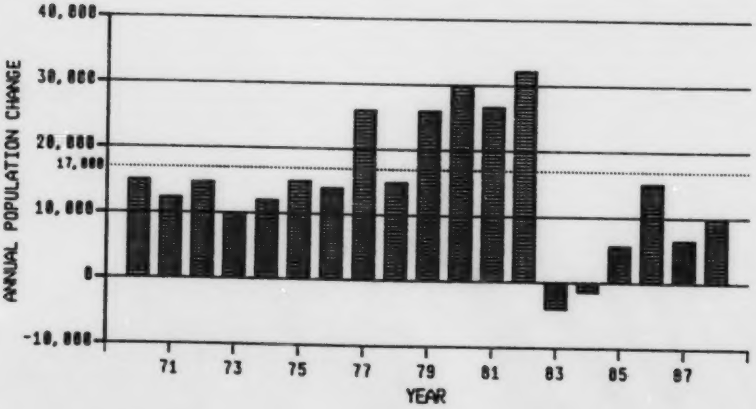


FIGURE 2

MARKET SHARE OF NEW SINGLE FAMILY UNITS, BY SECTOR 1975 - 1988

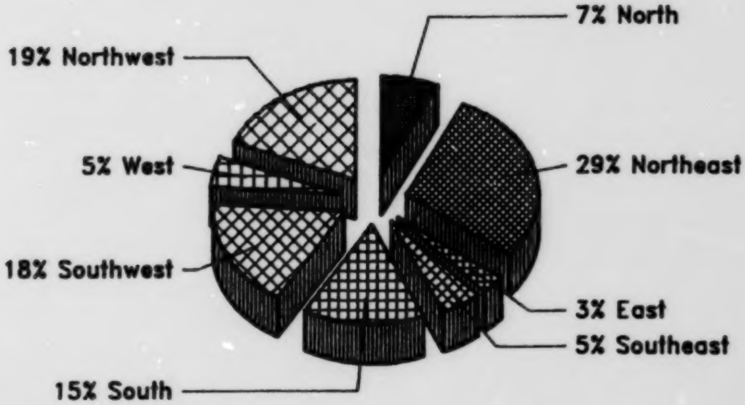
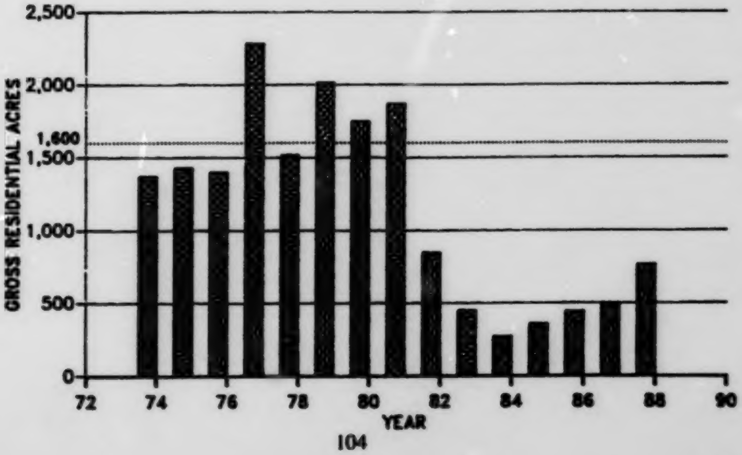


FIGURE 3

GROSS RESIDENTIAL ACRES SUBDIVIDED, 1974 - 1988



Simultaneous growth in all directions coupled with the City's role in front-ending the major infrastructure needed to service new growth areas provided several distinct advantages under rapid-growth conditions:

1. Home-buyers benefitted from having a wide variety of residential areas and housing styles available at any given time, and the possibility of active competition among developers and home-builders probably helped to keep house price increases to more moderate levels.

2. Land developers and home-builders could all be actively involved in some market segment and carry-out their business under competitive conditions.

3. The City was able to meet the demands of rapid growth in a manner which provided choice in the marketplace at a price that many could afford. All Calgarians enjoyed the benefits of new and improved amenities and services while, at the same time, seeing their property values steadily increase.

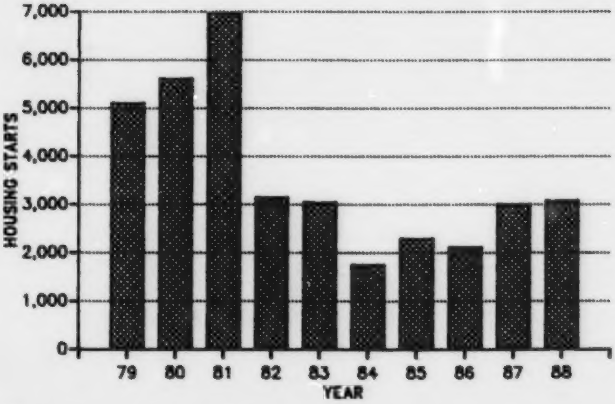
4. Off-setting the City's capital expenditures for infrastructure extensions and upgrading was a steadily growing tax base, capable of financing utility extension costs in the interim, until the front-ending costs were fully recovered through development (which was occurring at an very buoyant pace).

The "boom" of the 1978-82 period added fuel to an already heated economy, with single-family housing starts peaking at about 7,000 units in a single year (see Figure 4). The resources available to accommodate this growth, which was now exceeding 32,000 people (a 5.5-percent growth rate) in a single year, were being stretched to their limits. At the same time, the consequences of ever increasing growth were apparent in the steady increase in house prices and the possibility of new-housing shortages.

While the City had little control over the amount of growth to be accommodated, it was able to satisfy the demand for serviced land through its growth management policies. The magnitude of the City's expenditures to service growth, in view of the growing tax base and the consequences of not providing enough serviced land, together supported the view that it was both desirable and necessary to extend City infrastructure in response to demand.

FIGURE 4

SINGLE FAMILY HOUSING STARTS, BY YEAR, 1979 - 1988



A SUDDEN CHANGE OF CONDITIONS

The economic downturn of 1982 sent all of the major players - land developers, home builders and buyers, municipal administrators, and local politicians - into a tailspin. Where only one year earlier the City had grown by 32,275 people, it now faced the reality of loosing roughly 4,000 people in 1983. Systems designed to respond to very high levels of growth were now facing drastic adjustments.

The effects of the downturn became immediately visible in slower house sales and reduced land development activity. The City quickly realized that the cost-recovery prospects for recent infrastructure extensions would not materialize within the time frames anticipated. Further, the City's ability to carry this debt for an extended period would be made more difficult over time, since the expected level of growth in the municipality's tax base was also being undermined.

As if this situation was not difficult enough, the City was, at the same time, being approached by residential developers to extend the City infrastructure into what the developers felt were still "viable" (although as yet unserviced) development cells.

RECOVERING PAST INVESTMENTS IN INFRASTRUCTURE EXTENSIONS

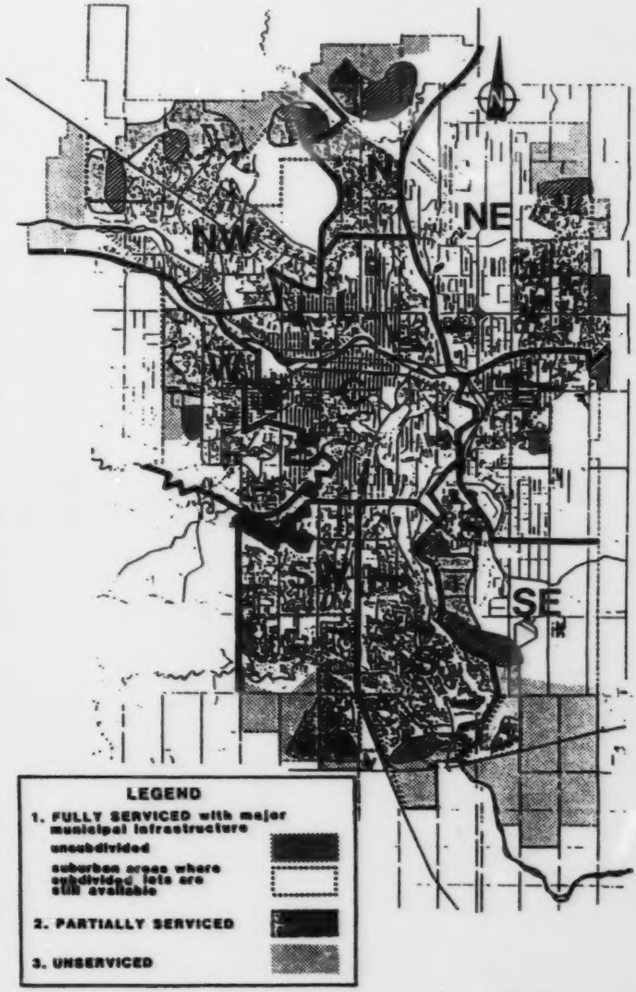
The City had, at this point, an estimated $37 million already invested in relatively new storm and sanitary sewer facilities, an investment which could only be recovered (and then, only in part) through the development of those serviced lands shown on Map 1. And while that investment had been necessary to service growth the year before, it was now being regarded as an under-utilized resource which was, in the short-term, generating a substantial carrying cost for the municipality.

Extending the cost-recovery period for major utility extensions can have serious consequences for both land developers and the City. Under the financing scheme in place, the front-end costs of installation are pro-rated, on a per-acre basis, over the lands serviced by the utility extensions. The City, in the role of banker, incurs the annual financing cost and builds that cost into the per-acre charges in each service area for the subsequent year. Under slow-growth conditions, this approach presented two problems:

- The City was facing higher than anticipated interest charges, with lower levels of development to generate cash-flow.
- The charges for utility extensions (referred to as "acreage assessment charges") were increasing in serviced areas at a rate of 11 percent annually. (Figure 5 illustrates the impact of this annual rate increase in a service area which had been serviced during the "boom" years but has yet to see any housing construction).

The extension of services into the area pertaining to Figure 5 illustrates one of the consequences of pre-mature investment. (While this example actually occurred in Calgary, it reflects the most dramatic situation experienced to date.) In this case, storm sewer trunks were constructed in the area in 1981, although the anticipated development did not materialize. Had development occurred in 1983, the developer would have paid $8,807/hectare for storm sewer assessments. Should development occur in 1989, the same developer in this area will pay roughly $16,300/hectare - paying, in effect, an appropriate share of the accumulated carrying cost of financing the trunk since 1981. Until development of these lands occurs, the City will incur additional carrying charges. As such, it is clear that both the City and the developer carry the risk that development might occur more slowly than anticipated.

MAP 1
LOCATION OF RESIDENTIAL LAND SUPPLY IN SUBURBAN AREAS, BY SECTOR


NW
N
NE
W
C
E
SW
S
SE
LEGEND
1. FULLY SERVICED with major municipal infrastructure
unsubdivided
suburban areas where subdivided lots are still available
2. PARTIALLY SERVICED
3. UNSERVICED

Note: This map illustrates only future residential areas. There also exist substantial non-residential areas which are fully or partially-serviced.

THE CITY OF CALGARY

November 1984

Upon development, the landowner/developer incurs his share of the full financing cost to-date, which would be substantially lower if there had been a shorter interval between the time of utility extension and the ultimate development of the land. This point is illustrated in Figure 6, in which we imagine that this sewer trunk had been constructed in a year, say, 1987, that more closely coincided with the timing of development, which is now expected to occur in 1989. (This example assumes that construction costs remain in constant 1981 dollars.) The same developer bringing his or her land on-line in 1989 would pay a substantially lower acreage assessment charge in the latter instance: roughly $8,807/hectare instead of $16,300/hectare.

If the developer did not proceed for a number of years, it may be, from his perspective, less expensive to build a new trunk rather than tying into the existing trunk and incurring his share of its high financing cost. (While it is usually not practical to install a new trunk, the developer may argue that his assessment charge should be based on the cost of installing a new pipe today, leaving the municipality to absorb past carrying charges.) When the acreage assessment charges reach an unreasonably high level, as has been the case in some parts of Calgary, the industry and the City find themselves debating who can realistically assume past carrying charges - the City or the landowner? (It is noted that such a discussion is now underway in Calgary.) In such a situation, it is clear that it is in the interests of all parties affected to avoid this kind of premature investment.

But beyond this obvious conclusion, this situation raises the question as to whether the City should invest further funds to service new lands while a substantial inventory of serviced, but as yet undeveloped, land exists in many locations along the city's periphery. The servicing and development of new lands can only result in a slower build-out of the existing serviced land inventory and, as a result, the assuming of higher financing costs over the long term.

It is clear that the financing implications of existing and proposed utility extensions bears directly on the question of growth management in the short-term (0 - 5 years), and that the consequences of not managing the two together can be very serious for both the municipality and the landowners.

FIGURE 5

STORM SEWER AREA ASSESSMENT RATES
FOR THE NORTH BEDDINGTON STORM TRUNK

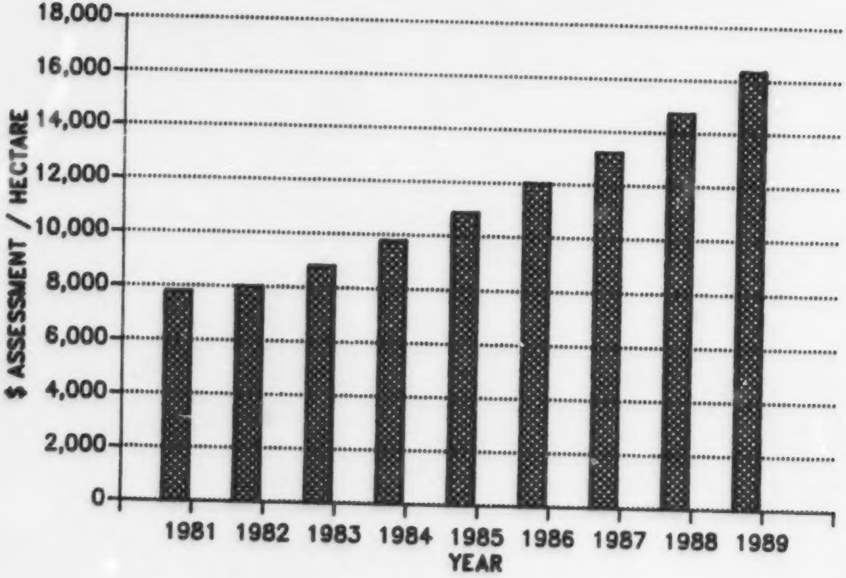
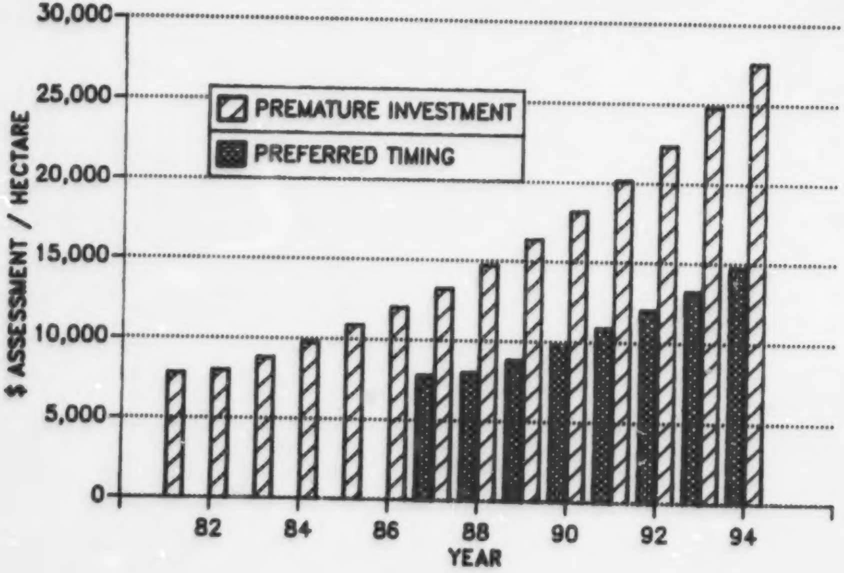


FIGURE 6

IMPACT OF INFRASTRUCTURE TIMING ON AREA ASSESSMENT RATES FOR THE NORTH BEDDINGTON STORM TRUNK



WHEN IS THE BEST TIME TO SERVICE NEW LAND?

The interests of each landowner, as compared to those of the City (in carrying-out its responsibility to manage the taxpayers' resources), may not coincide with respect to the timing of infrastructure extensions to service new lands for development.

From the developer's perspective, the best time to have the City extend services to his land is to have servicing in place by such time as he might reasonably expect to undertake development in response to his perception of market demand and the opportunities for his site. As such, his focus is on the dynamics of the marketplace (and its specific market segments) and, within that framework, on the share of the market that might be absorbed on his particular site. He is less likely to be concerned about the City's ability to pay for servicing his land (as that is what municipalities are supposed to do) or in how much serviced land supply there may be in other parts of the municipality (as he is mostly interested only in those lands which might effectively compete with his own site).

The City, on the other hand, may be concerned about satisfying the demand for serviced land and housing and, in addition, be concerned about the efficiency with which its past infrastructure investments are being used and how much additional debt it can or should absorb in servicing the demands of new growth. As such, the City wrestles with such questions as:

- How much inventory of unused infrastructure is necessary in providing an adequate float of serviced land to support a competitive, healthy marketplace?
- How much variety (i.e., how many developers and how many locations) is needed in the marketplace to ensure competitive prices and a choice for consumers?
- What priority should be given to upgrading services in existing built-up areas of the city as opposed to providing that extra element of competition and choice in the new home market?

In experiencing a dramatic change in circumstances in 1982, the City of Calgary was faced with opposing pressures both to continue capital spending for new growth areas and, at the same time, to show restraint in spending and more effective management of its existing resources, i.e., unused infrastructure carried over from the earlier "boom" period. These circumstances called for a re-thinking of how growth was to be managed, and how services were to be financed.

SHORT-TERM GROWTH MANAGEMENT STRATEGY

In response to this situation, city council directed that the Administration prepare a growth management strategy to provide a framework for evaluating the need for and timing of new infrastructure extensions on an annual and 5-year budgeting basis. The strategy was to be developed in consultation with all affected civic departments and representatives of the development industry.

The strategy was approved in February, 1985, with the support of the development industry. The intent of the strategy was twofold:

- to provide for an efficient utilization of the existing City infrastructure; and
- to allow capital budget decisions relating to the extension of this infrastructure to be made in the context of the overall servicing needs of the city, and the municipality's financial capability.

At the same time, it was recognized that the short-term strategy must respect the City's long-term growth policies, as outlined in the general municipal plan. That is, the policies in the strategy would relate only to the timing of City expenditures and not override or challenge the land use policies that were already in place in various planning documents.

The strategy contains six statements (reported here subsequently) with each of the statements contributing in a different way. Statements #1 and #2 establish the policies of the strategy with respect to the use of existing infrastructure and decisions relating to the extension of new infrastructure within a city-wide context. Statements #3 and #4 outline the two processes involved in the strategy, the first being the normal planning and budgeting process, and the second creating the opportunity for city council to consider those *ad hoc* development proposals which require infrastructure extensions, each on its own merits. Statements #5 and #6 are included to ensure that the strategy remains current and relevant.

Statement #1

The City will endeavour to accommodate growth while, at the same time, attempting to avoid premature investment in municipal infrastructure.

Underlying this policy is a recognition that the City has already made a considerable investment in infrastructure in some areas and that delayed development can result in increasing assessment charges in the future. The strategy clearly states that the City would prefer to see development located where existing infrastructure is already in place. However, the policy does not go so far as to say that development must occur on lands which are already serviced, thereby leaving a door open for the possibility of service extensions within the context of Statement #4.

Statement #2

Through the normal budgeting process, decisions about capital expenditures relating to the extension or upgrading of municipal water, storm, sanitary, and transportation systems, or increases in electric substation capacity will be made after consideration has been given to:

- the overall capital cost implications of the extensions, including the cost of the other services the City provides in addition to those listed;
- an understanding of the City's financial capability;
- existing market conditions and anticipated demand as they relate to the proposed expenditure;
- the current status of the total municipally serviced land inventory; and
- the impact of these decisions on the provision of gas, telephone, and cable services.

This policy indicates that the growth management information is to provide a basis for the City's normal capital budgeting process (for annual and 5-year budget forecasts) and is not a substitute or alternative for that process. The Administration, then, is required to present capital budget proposals in the context of anticipated housing demands, the availability of serviced land in other locations, and the City's capacity to assume more debt for this purpose. Annual capital budget decisions will be made in the context of market trends, the industry's needs, and the City's willingness to budget for the extension.

Statement #3

The City will make every effort to build sufficient planning, budgeting, and design lead times into the normal planning and budgeting process to allow the City to be in a position to construct the municipal infrastructure necessary to provide the supply of serviced land determined to be necessary under Statement #2.

The intent of this statement is to assure the marketplace that the City will endeavour to provide a sufficient inventory of land with municipal servicing capacity in place. On an operational level, this has been interpreted to mean that at least a 2- to 3-year inventory of serviced lots and sites would be maintained in every sector (which provides more than a 2- to 3-year inventory on a city-wide basis).

This approach leaves the City in a better position to schedule the construction of new infrastructure in a given sector more closely to the actual need, as demonstrated by observed market activity and short-term growth forecasts. While the City would encourage developers to work through technical servicing solutions several years in advance of development, City funds would only be expended immediately before the developers themselves were about to proceed with the installation of shallow utilities, e.g., telephone, cable, and natural gas.

Statement #4

Where a development is proposed to the City Engineer for which financial commitments for municipal infrastructure are required but are not budgeted for, a report, along with the proposal submitted, will be brought by the Administration to the operations and development committee and city council for review. This report will provide an evaluation of the budgetary and financial implications of the proposal to the City, in addition to the evaluation of other factors that may be relevant to the greater public interest. City council will then determine whether the municipal capital investment is justified in the greater public interest.

This process provides owners of land lying outside serviced areas to have the opportunity to put forward proposals to the Administration and city council for consideration. Developers, through this process, can promote the unique merits of their application and suggest various imaginative financial solutions to lessen the financial burden of their proposed development on the City. In assessing the merits of a proposal, city council also considers the financial implications of the development not taking place on land which is already serviced, i.e., the impact of acreage assessment charges not being received from the alternative, presently serviced lands.

Statement #5

A review of the policies contained in the management strategy for short-term growth may be requested by the Administration, The Calgary Home Builders Association, or the Urban Development Institute. This review will be undertaken by the Administration in consultation with the development industry.

In recognizing that circumstances change, and that these statements may require fine-tuning after a period of implementation, city council wishes to provide every opportunity for the strategy to be reviewed, if required.

Statement #6

The information base of the strategy will be updated annually to ensure that city council has the most current information available when implementing this strategy.

This directive was intended to ensure that a detailed information base was continuously updated. Documentation of the information base is available in the City's publication entitled "Short-Term Growth Management Information Up-Date, 1988 - 1992".

The information updating is undertaken annually in consultation with representatives of the building and development industries in an effort to compile the most current, relevant, and objective information available.

The "Information Up-Date" report provides a logical summation of relevant facts and forecasts, but it does not contain any recommendations. As such, it is able to provide all parties with a common source of information to which everyone can agree. The information is then fed into the normal budgeting process (as described in Statement #2) and into the review of *ad hoc* proposals (as described in Statement #4).

It is to be noted that agreement on the "facts" does not necessarily result in agreement between the City and the industry on matters of policy or spending priorities. However, it is clear that having a shared, credible information base substantially improves the opportunity for more constructive and focused discussions with regard to policy and spending priority issues between all parties.

HOW HAS THE SHORT-TERM STRATEGY PERFORMED TO DATE?

The strategy, and its related information reports, have proven to be a very valuable management tool in many areas of municipal involvement, notwithstanding that it has only been operational for 4 years. A few examples of its impact on the City's planning and budgeting operations will illustrate how far-reaching this approach can be.

As a Planning Tool

The "Information Up-Date" report is now used as the principal source of information related to current land and housing development activity, short-term land requirement forecasts, and up-to-date utility servicing requirements within the suburban area. The report provides some information which was previously undocumented and presents data from a variety of sources in a concise, integrated package. The fact that the report is prepared jointly by a number of departments and agencies, and reviewed in detail by representatives of the home-building and development industries, lends credibility to the completeness and objectivity of the information base.

By identifying the expected supply/demand conditions within each sector for the coming 5-year period, the report provides a consistent basis for all servicing departments to use in designing their 5-year budget proposals for those areas likely to experience serviced land shortages in the short-term. In this way, the City is placed in a stronger position to manage the timing of infrastructure extensions better, and so lessen the risk of premature investment in specific areas.

The City also has a more realistic information base to assist city council in balancing the relative priority of servicing new growth areas with the maintenance, upgrading, and replacement needs of older infrastructure in established areas throughout the city.

The strategy and the "Information Up-Date" report have provided strong evidence of the City's initiatives aimed at managing its debt and future expenditures in a comprehensive manner; i.e., both through financial and through growth management mechanisms. Having the strategy in place was a contributing factor in the City's maintaining its "AA" credit rating, notwithstanding its having to endure the harsh consequences of the 1982 recession.

As a Forum for Open Dialogue With the Industry

The strategy provides specific mechanisms to ensure the involvement of industry representatives in the preparation of the annual "Information-Up Date" report (Statement #6) and the review of the strategy's policy base (Statement #5) on an as-required basis. For individual developers, the strategy guarantees that each development proposal requesting major City expenditures will be presented to city council and considered on its own merits, should the proponent choose to pursue his request to that point.

As a Tool for Evaluating Immediate Capital Expenditure Requests

The information base and review processes outlined in the strategy have provided a framework for the Administration's review of several immediate development proposals that would have required City expenditures of several millions of dollars. In many instances, the review determined that the servicing expenditure could not be substantiated given current market and land supply conditions. A number of the requests were withdrawn, at the developers' initiative, and the City did not undertake the infrastructure extensions.

The rigour with which these proposals are now evaluated by the Administration demands that the applicants provide a thorough explanation as to how their proposed land absorption (i.e., new home construction) fits into the sector and city-wide demand/supply picture. As such, the review process helps to make explicit the many market assumptions that underlie the development proposals.

Recently, the review processes created by the strategy have been expanded to include the evaluation of major industrial proposals and the annual "Information Up-Date" report will be expanded to address supply/demand conditions for the industrial land base as well.

As a Forum for Innovation

In several instances, where the case for immediate City expenditures could not, in the Administration's view, be substantiated, the applicants were given an opportunity to propose other "creative" servicing or financing solutions which might lessen the City's expenditures or risk exposure. These solutions, some of which are now under review, provide interesting alternatives to the way in which things have traditionally been done in Calgary. A few examples include:

- a developer's willingness to re-design the water system for a proposed development cell in such a way that the developer absorbs distribution costs and forestalls the need for a major system watermain (which would normally be at the City's expense);
- a developer's willingness to front-end the cost of sewer trunks and assume the full financing costs until the City would have otherwise extended utilities into the development cell (in response to the strategy's assessment of the need to open-up additional serviced lands in that particular sector); and
- a developer's proposal that the City consider constructing its expressways in a series of incremental stages to provide immediate access for development without requiring that the City assume the full cost of constructing the ultimate facility. (The possibility of the developer assuming the construction and maintenance costs of the initial stage is also being reviewed).

As a Forum for Evaluating Major Growth Management and Financing Projects

The "Information Up-Date" report provided an important source of information for a special aldermanic task force reviewing the City's financial management strategy in 1988. As a consequence of city council's consideration of their report, the director's growth management steering committee was directed to review two important areas of City policy and operations by addressing the following questions:

1. Should the City continue to maintain a serviced land supply in every growth corridor in the short-term, or is it reasonable and prudent to delay infrastructure extensions in particular development areas in order to

encourage a fuller utilization of service capacity where it exists, and avoid taking on additional debt for new extensions?

2. Is the current system for financing utility extensions likely to work well for the City over the long-term? What alternative means of financing infrastructure extensions should city council also be considering at this time?

These questions are currently being addressed by the directors' growth management steering committee and will be considered by city council later in 1989.

CONCLUSIONS

Opportunities may exist for many municipalities to manage growth in ways which achieve the fullest use of existing infrastructure and, at the same time, lessen the burden of new expenditures for servicing growth.

In managing growth through the timing of infrastructure extensions, it is important that a clear policy base be in place to establish the framework within which development and financial management decisions can be worked through in an integrated way. In supporting this framework, it is essential that a current, reliable information base be available to serve the evaluation and decision-making process.

On the basis of Calgary's experience, it is highly desirable, if not critical, that the affected industries (i.e., land development and house building) participate directly in developing the policy and information base, and in maintaining an open and on-going dialogue with the municipality's planning, engineering, and management staff. It is equally important that, through the evaluation processes, landowners be assured an opportunity to present the merits of their proposal (where it involves major capital expenditures on the municipality's part) to city council directly.

It is apparent that the benefits of having such a strategy, in terms of making better decisions, touch many areas of municipal activity, e.g., planning, engineering, financial management, etc. And of no less importance, the processes involved in carrying-out this approach strengthen the working relationships both among civic departments (resulting in an integrated "civic view" of growth and infrastructure management) and between the municipal administration and the development industry.

NEIGHBOURHOOD INFRASTRUCTURE PROJECTS IN EDMONTON

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ABSTRACT

The City of Edmonton is spending $15 million each year on a unique program to replace the infrastructure in selected older neighbourhoods. Three things make it unique: provincial funding of infrastructure, maximum use of private sector resources, and integration of infrastructure replacement with community amenity enhancement.

The neighbourhood focus allows coordinated planning, engineering, and construction as well as a street landscaping component and improved public communication and participation.

So far $20 million has been spent on the first three neighbourhoods.

This paper presents the background to Edmonton's infrastructure problems and why we decided to start this neighbourhood program, details of the program, and the results of the program so far.

RÉSUMÉ

La Ville d'Edmonton consacre annuellement 15 millions de dollars à un programme unique de remplacement des infrastructures dans certains quartiers. Trois facteurs le rendent unique : le financement des infrastructures par la province, l'usage maximal des ressources du secteur privé, et l'intégration du remplacment des infrastructures et de l'amélioration des équipements collectifs.

En faisant porter l'attention sur les quartiers, la municipalité peut ainsi coordonner la planification, les travaux de génie et de construction, aménager les rues et améliorer la communicipation et la participation du public.

Jusqu'à présent, les dépenses touchant les trois premiers quartiers touchés se chiffrent à 20 millions de dollars.

Le présent document trace l'historique des problèmes d'infrastructure à Edmonton et explique les raisons ayant motivé les autorités à entreprendre ce programme

d'amélioration des quartiers, en plus d'exposer le programme dans les détails et de faire état des résultats obtenus jusqu'ici.

HISTORY

Edmonton's first municipal water and sewer systems were constructed in 1902. Population growth has been continuous from 5,000 then to 600,000 today.

Expansion of the population and associated infrastructure was most rapid before World War I due to service agricultural expansion, during the early 1950s after the discovery of oil, and in the late 1970s when high energy prices stimulated development in Alberta (see Figure 1).

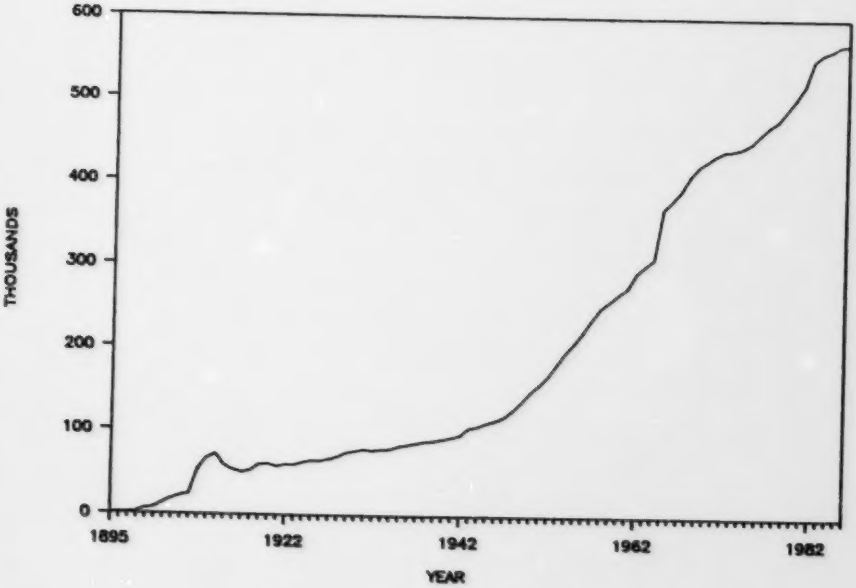


FIGURE 1: City of Edmonton Population.

Infrastructure Problems

Until the 1960s, cast iron had been the preferred material for watermains. Then the number of breaks started to increase year by year (see Figure 2). Cast-iron pipe was not installed by the city after 1966, although cast-iron fittings are still used, but the number of breaks continued to increase dramatically. The areas of the city most affected are identified in Figure 3.

The drainage system in the older areas of the city was originally constructed as a combined sanitary and storm sewer system (see Figure 4). Since the 1960s, separate storm drainage has been provided in new areas and some storm sewers were constructed in older areas. Flooding of basements during storms was and remains the most serious problem in the drainage system.

Most roadway expenditures go towards the construction and reconstruction of arterials. Most of the 2,500 km of paved roads are local roads, however, which provide residential access, and there is only a small program for the replacement or overlay of these. It would take 100 years to replace local roads at the present rate of replacement.

Sidewalks in many older residential areas are in relatively poor condition.

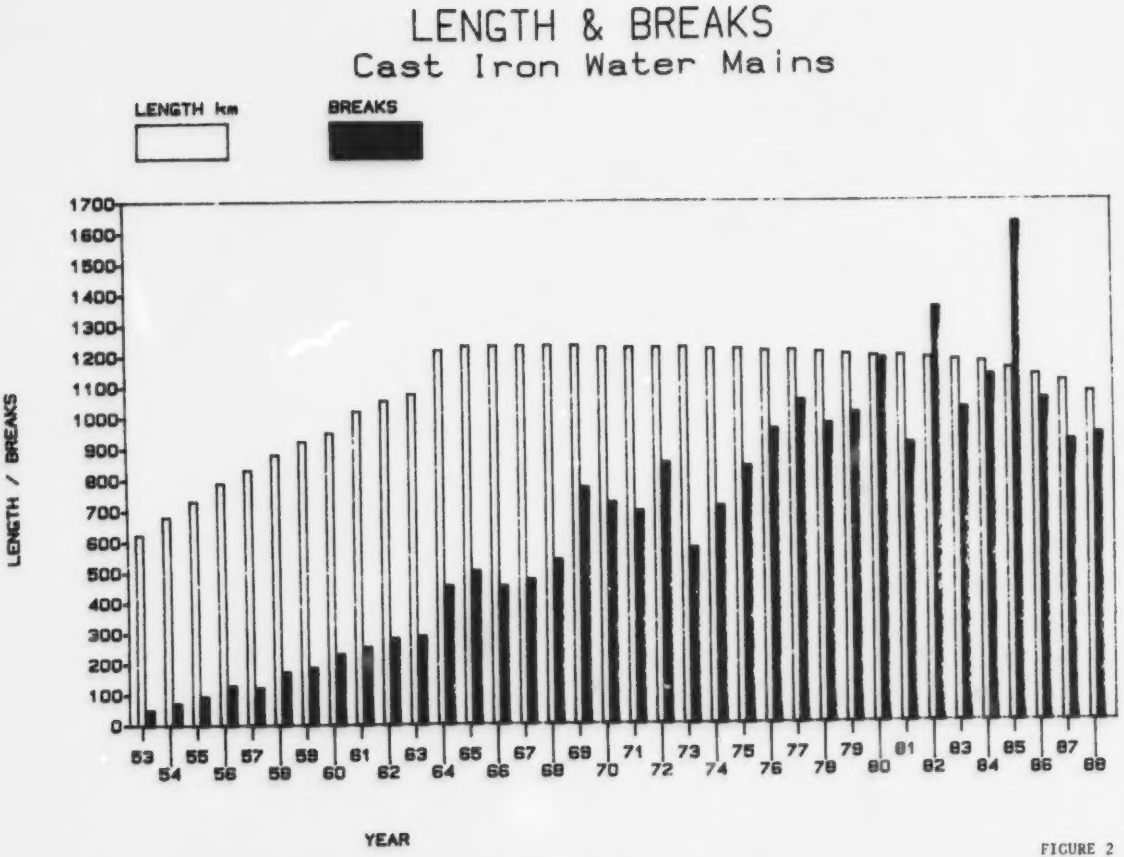
Natural gas was brought to Edmonton in the 1920s and the original bare steel distribution pipes now need replacement because of corrosion. Northwestern Utilities Ltd. is the gas franchise holder and has started a major program to replace all these pipes over a 10-year period (see Figure 5).

Infrastructure Management

The responsibilities for management of our infrastructure lie with a number of different City departments and utilities.

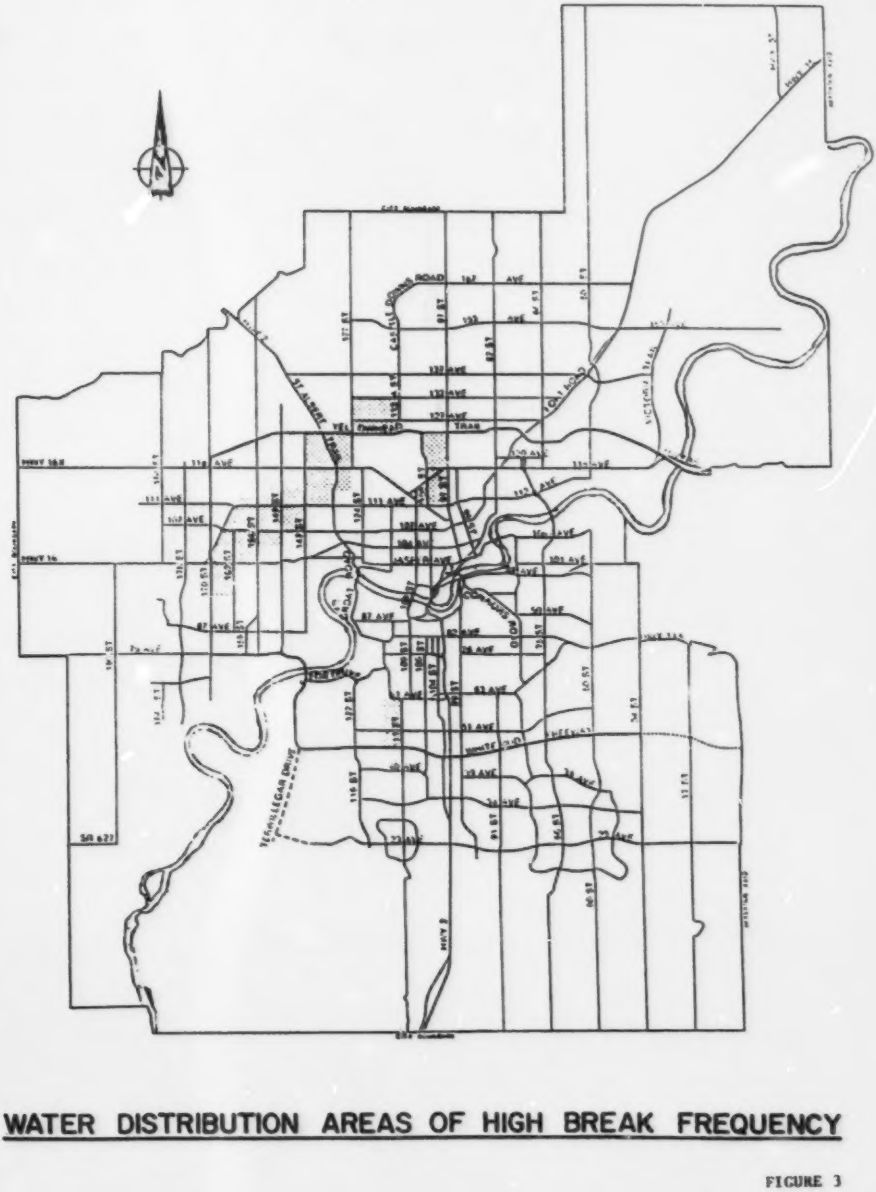
Staff assigned to the City's water system responded to the increase in watermain breaks by expanding the repair of breaks into a small replacement program when time and money allowed. When this was evidently insufficient, the funmding for the program was increased to $7 million/year.

Flooding problems in the central area of the city were addressed by a 1972 plan to increase the storm drainage capacity of the combined sewer system. The initial funding strategy was a redevelopment levy, but this was replaced in 1985 by a city-wide surcharge on the utility bills.



LENGTH & BREAKS
Cast Iron Water Mains

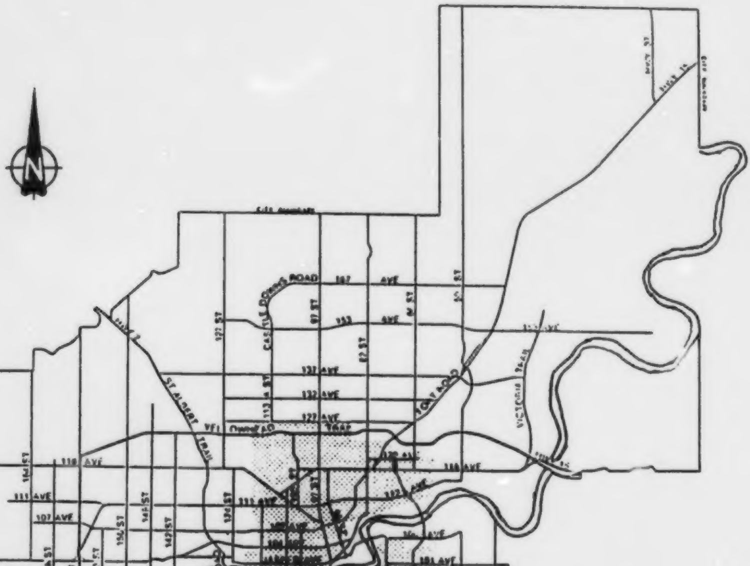
FIGURE 2



CASTLE DOWNS ROAD
167 AVE
153 AVE
137 AVE
132 AVE
127 AVE
ST ALBERT TRAIL
YELLOWHEAD TRAIL
FORT ROAD
VICTORIA TRAIL
HWY 16X
118 AVE
111 AVE
107 AVE
HWY 16
JASPER AVE
GROAT ROAD
87 AVE
82 AVE
76 AVE
CONNORS ROAD
63 AVE
51 AVE
WHITEMUD FREEWAY
34 AVE
23 AVE
TERWILLEGAR DRIVE
SR 627
HWY 2
97 ST
82 ST
50 ST
127 ST
170 ST
149 ST
142 ST
199 ST
91 ST
34 ST
17 ST

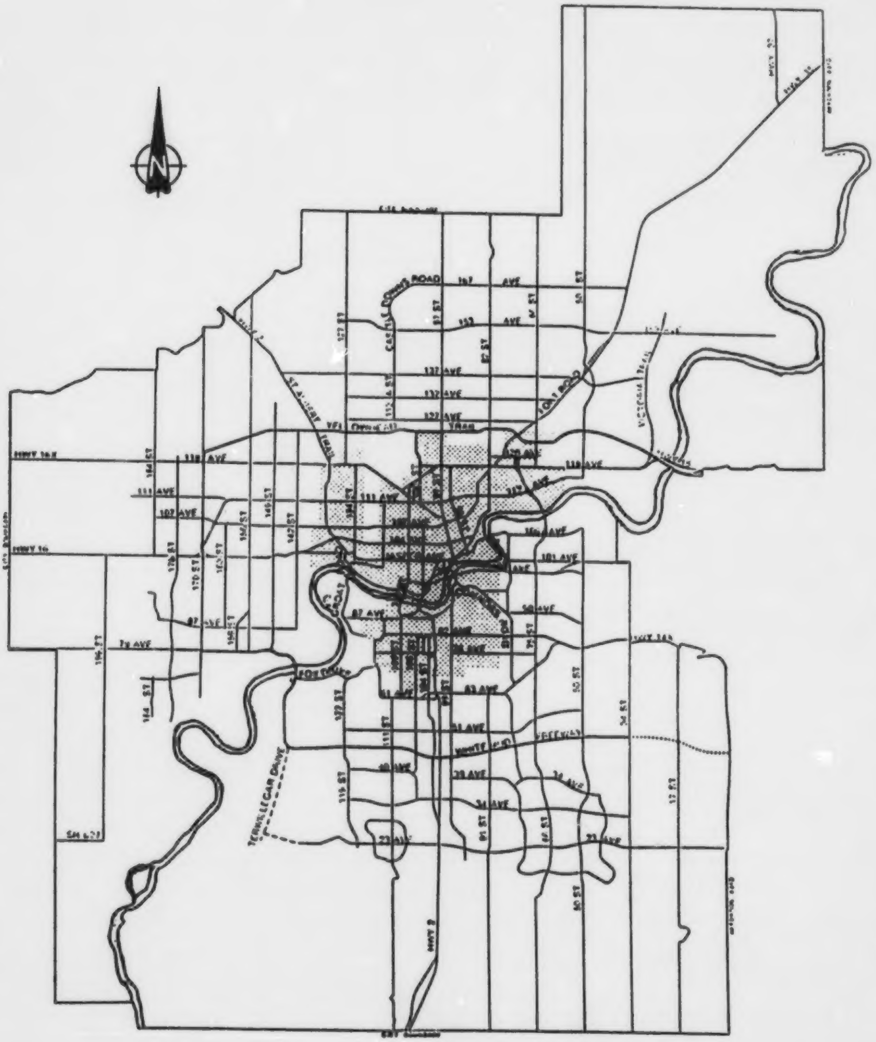
WATER DISTRIBUTION AREAS OF HIGH BREAK FREQUENCY

FIGURE 3


N
CITY BOUNDARY
CASTLE DOWNS ROAD
167 AVE
153 AVE
137 AVE
132 AVE
127 AVE
YELLOWHEAD TRAIL
ST ALBERT TRAIL
FORT ROAD
VICTORIA TRAIL
118 AVE
HWY 16X
HWY 16
111 AVE
107 AVE
87 AVE
79 AVE
FOX DRIVE
TERWILLEGAR DRIVE
WHITEMUD DRIVE
SHERWOOD PARK FREEWAY
HWY 14X
23 AVE
SR 627
HWY 2
50 ST
34 ST
17 ST

COMBINED SEWER AREA

FIGURE 4


N
CASTLE DOWNS ROAD
167 AVE
153 AVE
137 AVE
132 AVE
127 AVE
118 AVE
111 AVE
107 AVE
101 AVE
90 AVE
87 AVE
82 AVE
63 AVE
51 AVE
40 AVE
38 AVE
34 AVE
23 AVE
HWY 16X
HWY 16
HWY 14
HWY 2
FORT ROAD
WHITEMUD FREEWAY
TERWILLEGAR DRIVE
FOX DRIVE
VICTORIA TRAIL
97 ST
82 ST
66 ST
50 ST
34 ST
17 ST
91 ST
111 ST
119 ST
122 ST
127 ST
142 ST
149 ST
156 ST
163 ST
170 ST
178 ST
184 ST
SH 627

GAS DISTRIBUTION BARE PIPE REPLACEMENT
(NORTHWESTERN UTILITIES LTD.)

FIGURE 5

Road management has been directed toward grant-funded programs for major roadways. Only smaller expenditures from the general property tax can be used for repairing local streets and sidewalks. Property owners have resisted local improvement taxes to pay for reconstruction.

Financing

The City has its own two sources of funding for infrastructure construction/ replacement: utility surcharges and property taxes.

The watermain replacement surcharge on customers' utility bills generates $7 million each year, slightly less than 10 percent of water revenues and sufficient to fully fund the pipe replacement program at a rate of approximately 18 km/year.

The drainage surcharge raises approximately $8 million each year, sufficient to pay for a $4 million relief program in the combined sewer area, and $4 million for the upgrading programs in other areas of the city.

General property taxes pay under $1 million/year for local road reconstruction and $3.5 million for resurfacing. This excludes arterial road projects. Bridge repairs and rehabilitation cost $0.5 million/year.

So by 1986, the City was spending approximately $20 million each year on infrastructure replacement.

The provincial government and the municipalities were attempting to reduce persistently high unemployment rates. The Alberta Municipal Partnership in Local Employment (AMPLE) was created in 1986 by the Province as an unconditional grant program, and municipalities were encouraged to use the funds for employment creation through public works. A total of $500 million is being distributed to Alberta municipalities over 8 years.

THE NEIGHBOURHOOD PROGRAM

The halt in rapid urban growth since 1982 allowed the City to look more closely at the problems of deteriorating infrastructure. At the same time, city planners also refocused attention on older neighbourhoods and the downtown core and a number of area planning documents were produced from study and consultation with residents.

The City's interest in infrastructure repair and the AMPLE program coincided. As can be seen from Figures 3, 4, and 5, there are overlapping infrastructure needs in some areas of the city. Because of this and in order to maintain the visibility of the AMPLE program, selected older neighbourhoods became candidates for a neighbourhood infrastructure program. A small committee of City staff selected the first three neighbourhoods and established a budget of $40 million.

Inglewood, Westmount, and Oliver were the selected neighbourhoods. Situated to the west of downtown, they include residential developments up to 90 years old and business developments along major roadways (see Figure 6).

Objectives

The objectives for the AMPLE program are:

1. Fix decaying sewers, watermains, and roads.
2. Create employment.
3. Coordinate and integrate construction with community upgrading plans.
4. Use private sector resources.

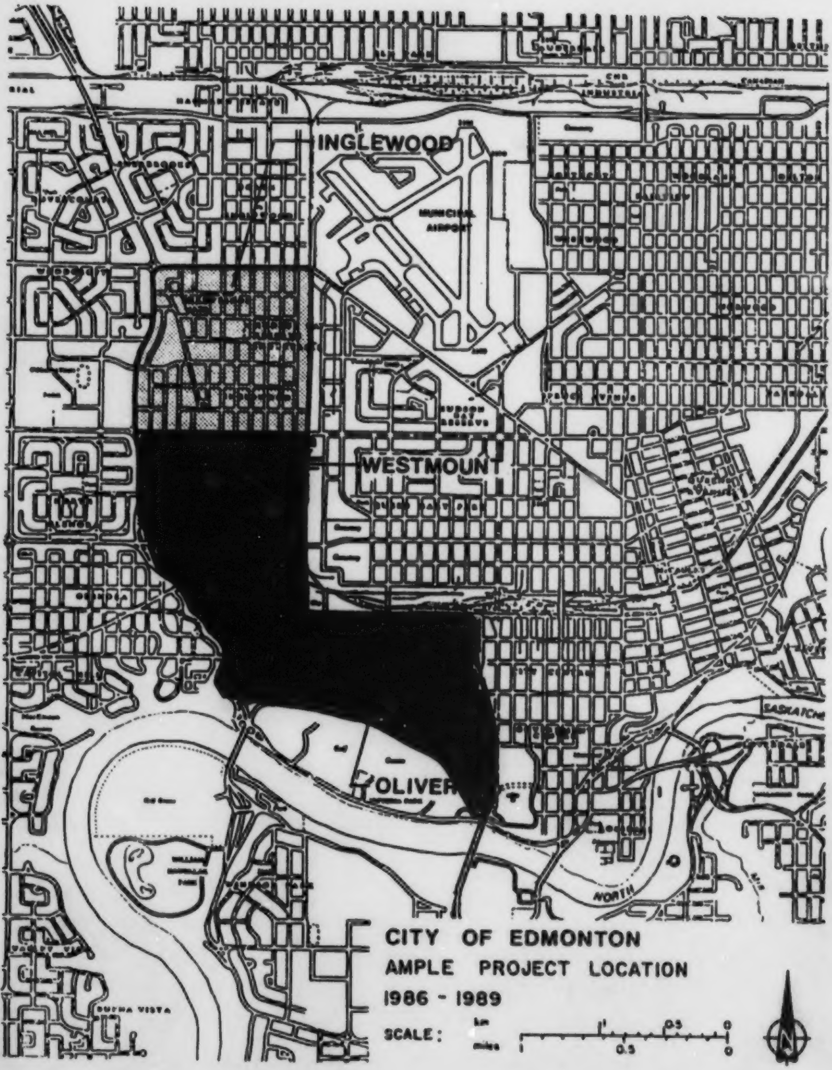
A key decision was the integration of planning and construction of watermains, sewers, and roads. For many years, in Edmonton the water, drainage, and road systems have been managed by separate departments, each with their own priorities. While servicing of new areas has been well coordinated, infrastructure replacement priorities have been different for each department.

Another significant decision was to involve the resources of the City Planning Department to make the project more than just an engineering venture. Area development reports and community improvement studies had been completed in some neighbourhoods, but few of the suggested improvements had been implemented.

Management Process

Each city department reports through a general manager to the city manager and then to city council. The three general managers involved (Planning, Transportation, Water & Sanitation) constitute a steering committee. They appointed the project manager and one representative from each department to coordinate the program development and implementation: a coordination committee. All engineering, community planning, and construction projects were to be contracted to the private sector, with city staff providing policy development and review functions.

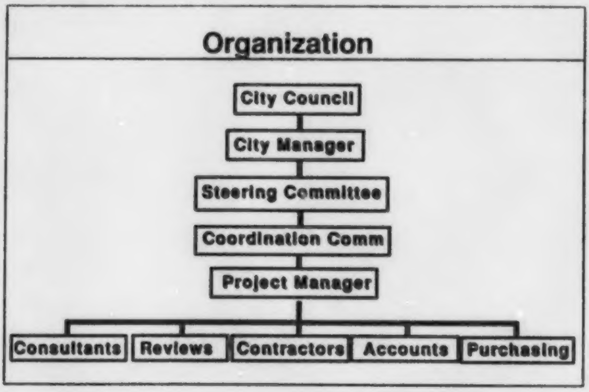
The management structure (see Figure 7) achieves several positive results. The two small committees meet regularly and require only short times to cover agendas. The project manager has almost sole responsibility for the smooth implementation of the


INGLEWOOD
MUNICIPAL AIRPORT
WESTMOUNT
OLIVER
NORTH
SASKATCH
SCALE:
km
miles
1
0.5
0

CITY OF EDMONTON
AMPLE PROJECT LOCATION
1986 - 1989

FIGURE 5

project, utilizing a "flat" organization where many city staff groups, consultants, and contractors have direct contact to the project manager. The organization, unburdened by much bureaucracy, is responsive and decisive.



On the other hand, because the group is small and "outside" the traditional City hierarchy, few others know what is going on and communication does not flow effortlessly through the various city departments. City staff participating in the various processes may not always receive "line" recognition for their contribution to the AMPLE project.

Design and Construction Phase

Consultants were selected in 1986 to provide reports on the condition of the City's infrastructure, one consultant for each neighbourhood. In addition to the engineering analysis of water, sewer, and road systems, each consultant was requested to review and develop ideas from existing community planning documents and, above all, implement a communications plan to inform and involve local residents and businesses.

By mid-1987, reports on what needed doing had been reviewed by the City. The consultants then prepared a 3-year schedule of construction contracts for design and construction.

Gas lines were already proposed for replacement at some time during the 1987-1996 period, and Northwestern Utilities Ltd. willingly tailored its replacement program to match the AMPLE project locations and allow concurrent work.

While the engineering analysis quickly defined the extent of the roadway, sidewalk, watermain, and sewer replacements, the landscaping improvements along the streets were of greater concern to the residents and took more time to detail. Simple projects, such as infilling the missing boulevard trees and constructing ramps for handicapped persons at intersections were easy to agree on. Determining the extent of historical themes, routing bicycle traffic, finding traffic and parking solutions, and reaching compromises between roads and sidewalks, business parking and residential parking - all these activities required community participation processes that continued throughout the project.

The expenditure plan is shown in Table 1.

The first complete year of construction was 1988. Expenditures totalled $18.8 million on 17 contracts (see Table 2). Contracts generally included watermains, sewers, and roads in specific parts of each neighbourhood. Gas line construction was not part of the City's contracts; it was separately contracted by Northwestern Utilities Ltd. After installation of watermains and sewers, the City's contractor would move out allowing gas installations before returning to pave the lane or roadway. This process caused some delays and frustrations to contractors. To permit easier access for construction, temporary gas mains were installed on the surface while sewer and water construction occurred.

At the end of 1988, 13 km of watermains and 10 km of sewers had been replaced, 600 trees planted, and 4 km of roads paved. A park had been landscaped with surplus fill from the sewer excavations, saving on truck hauling costs, and designs for new landscape projects were reaching consensus.

Communications

A communications plan evolved quickly at the beginning of the project. Not only was it necessary to keep neighbourhood residents involved and informed but also other groups, such as city staff, elected officials, and the provincial government. Various media have been used as shown in Table 3.

Regular newsletters to the residents were published by the consultants and numerous public meetings and workshops were held in each neighbourhood. This established direct communication between the neighbourhoods and the consultants, and built trust which served well during the construction.

Table 1

EXPENDITURE PLAN ($ millions)

1986 - 1990

	WATER	DRAINAGE	ROADS	AMENITIES	TOTAL
INGLEWOOD	4.0	8.6	4.2	0.2	17.0
OLIVER	2.5	4.2	4.8	0.7	12.2
WESTMOUNT	2.8	5.1	3.0	1.0	11.9
	9.3	17.9	12.0	1.9	41.1

Table 2

LIST OF 1988 CONTRACTS

CONTRACT #	DESCRIPTION	LOW BID	CONTRACTOR
IW-2	Water/Sewer/Lanes	1,184,074	Volker Stevin
W-872	Water/Sewer/Lanes	1,420,450	Volker Stevin
W-874	Curbs & Gutters	154,885	D & H
0.1	Water/Sewer/Road	1,449,035	Voice
IW-3	Water/Sewer/Lanes	1,527,000	Kerna
0.2	Water/Sewer/Lanes	933,893	Eng-Con
W-873	Water/Sewer/Lanes	1,838,093	Standard General
0.3	Water/Sewer/Roads	657,379	Voice
IW-5	Water/Sewer/Roads	1,589,231	Babichuk
W-882	Water/Sewer/Lanes	1,831,419	Volker Stevin
0.4	Water/Sewer/Roads	1,000,257	Ras Dam
W-881	Water/Sewer/Lanes	1,221,242	Volker Stevin
0.12	Tree Planting	17,094	Heritage
W-883	Tree Infill	149,466	O'Brien
W-884	CNR Park Landscaping	216,203	Crown
0.5	Roads	567,560	Wells
IW-5B	Landscaping	70,771	Heritage

Table 3

COMMUNICATIONS PLAN

	AUDIENCE					
MEDIA	RESIDENTS	CITY STAFF	COUNCIL	PUBLIC	PROFESSIONALS	PROV.
Newsletters	X					
Community Meetings	X					
Construction Signs	X			X		
Press Releases	X			X		
"Ministream" Bulletin		X	X			
TV/Radio Interviews				X		
Technical Papers					X	
Tenders/Proposals					X	
Reports/Budgets		X	X			
Video Production	X	X	X	X		
Annual Meeting		X				
Annual Report		X	X			X

Customer relations were handled by the contractors and the consultants. This aspect of construction in urban areas was new to some of the contractors and consultants but this too was contracted out. Notifications of the work schedule, shut down of watermains, `etc. were given by the contractors. Consultants' field staff investigated complaints and helped to resolve them. In some cases, alternative parking for apartment residents had to be arranged or parking restriction signs temporarily removed. Complaints about mud, noise, and vibration were frequent, especially on weekends and summer evenings. In the middle of all this, Wayne Gretzky got married.

Public meetings attracted fair attendance (usually 40 to 50 people), and newsletters were sent to residents. The business community was more difficult to contact. Most of owners or managers lived outside the neighbourhoods and did not receive or read the newsletters. Often their first knowledge of construction was only 1 or 2 days in advance. Where a local business association was functional, meetings were held with them.

RESULTS

Many groups have benefitted from the successful implementation of this program.

City - Province

The program has achieved the initial objectives outlined earlier:

Fix Decaying Infrastructure. In each neighbourhood, the worst sewers, watermains, and roads have been replaced or repaired. As a result of the engineering studies, we know much more about the condition of our infrastructure. For example, all the sewers in these neighbourhoods were inspected with a TV camera, and we have been able to project the structural conditions encountered to other older neighbourhoods. We now estimate that 15 percent of our older sewers, approximately 600 km, need replacement city-wide.

We have already saved 70 breaks/year on the cast-iron water system in these neighbourhoods, reduced the number of basements flooded during major storms by bringing much of the storm drainage system up to current city standards, rebuilt the worst roads and sidewalk, and replanted missing trees.

Create Employment. It has been estimated that 150 person-years of direct employment were created in 1988. Spin-off employment might be double or triple this figure. Both the City and the Province have been able to see the employment created on the streets of Edmonton.

Coordinate with Community Plans. Public meetings, workshops, and surveys identified those surface improvements which could be done at the same time as the underground and road works. For example, linear systems of ramps for handicapped persons, walking and bicycle routes, information signs on neighbourhood history, pedestrian crossing improvements, street furniture, and trees were among the ideas developed and implemented.

A 2-way communication process between the communities and the City was enhanced and will leave the communities with new ideas and a springboard for further community improvements after the AMPLE program has finished.

The street amenity improvements have generally been inexpensive in comparison to the utility reconstruction work, but they have required effort to discuss and define. A number of community volunteers have helped the process along and the results have been increased community satisfaction with the construction.

Use Private Sector Resources. Before the AMPLE projects, all the engineering and reconstruction of infrastructure had been done by city staff. The work so far has demonstrated that the consulting engineers and the construction industry have the capability to do this work.

Comparisons between private sector and public sector are difficult to make fairly and accurately, but it appears that:

(i) Contract prices for watermain replacement were within 10 percent of what the City's own forces' cost would have been.

(ii) Contract prices for sewer work were perhaps 20 percent less than the City's own forces' costs would have been.

(iii) Housekeeping on the construction sites and public and worker safety were not as well managed by the private contractors.

(iv) Customer relations improved during the construction as the consultants and contractors became used to working in an existing urban neighbourhood.

(v) The City required minimum additional staff and management to deliver this program.

Consultants

The program has given local consultants more experience in the engineering of projects more complex than new subdivision designs. The community contact has also given the consultants more understanding of the public environment in which city staff work.

Contractors

The contractors have found that infrastructure replacement proceeds more slowly than they anticipated because of variable ground conditions, narrow lanes, traffic detours, and dealing with the public. Prices may be higher in 1989.

Communities

Fixing up the infrastructure is basic to the physical well-being of these neighbourhoods. There is overwhelming support for the final results of the construction and our customer surveys show 75 percent support for the way the construction was done. What we have shown is that we can do more than just replace the pipes and pave the streets. We have also made the neighbourhoods more attractive places to inhabit and left ideas and a process for interacting with the communities for the City's planning staff and the community groups to build on in future years.

REFERENCE

David, R. H. and Smith, G. J. 1987. "Rehabilitation of Municipal Services in Canada". Proc. First Canadian Conference on Urban Infrastructure, Sodanell Canada Inc., Edmonton, Alberta.

PUBLIC INTERACTION FOR DEEP-UTILITY RECONSTRUCTION IN A NARROW COMMERCIAL LANE

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ABSTRACT

This paper presents a case study of the interaction between the reconstruction of the deep utilities in a narrow residential/commercial lane and the businesses and residents who were affected. The expected problems of attempting to provide uninterrupted service and access are examined. In addition, problems with area parking and business deliveries are addressed as the requirements of different businesses may lead to many potential conflicts. The impacts of delays due to poor weather or unexpected working conditions are reviewed from the public's point of view. Elements for an effective public communication program are examined in light of the consultant's role being extended beyond traditional contract administration and resident engineering responsibilities.

RÉSUMÉ

Le présent document présente une étude de cas de l'interaction mettant en cause la reconstruction de services publics enfouis en profondeur dans une étroite voie commerciale/résidentielle ainsi que les entreprises et les résidents touchés. Il examine les difficultés prévisibles de la prestation d'un service et d'un accès ininterrompus, en plus de traiter des problèmes de stationnement et de livraison, puisque les besoins des différentes entreprises peuvent donner lieu à de nombreux conflits. L'exposé décrit l'incidence des retards occasionnés par le mauvais temps ou des conditions de travail imprévues, du point de vue du public. Un programme efficace de communication publique est étudié à la lumière du rôle du consultant qui va bien au-delà de l'administration du contrat et des responsabilités de l'ingénieur sur place.

INTRODUCTION

The City of Edmonton's Water and Sanitation Department instituted an infrastructure assessment and rehabilitation program in the fall of 1986. The project required the reconstruction of deep utilities (watermains and combined sewers) in a narrow commercial lane. Three neighbourhoods were selected to be included in this first phase of the program. This paper deals with one of the upgrading projects carried out in the Westmount area.

Upon completion of the Phase 1 Assessment Study of the municipal infrastructure (water; sanitary, storm and combined sewers; streets and lanes; streetscape) for the Westmount neighbourhood, the lane west of 124 Street between Stony Plain Road and 111 Avenue (an 8-block length) proved not only to have major system deficiencies but also that it was structurally in poor condition from all aspects of the municipal infrastructure. Phase 2 involved the design and construction of the approved rehabilitation program elements. Since the initial installation of the water and sewer mains in 1910, the land use has evolved to include commercial and multi-family residential uses on 124 Street, while the 125 Street west side of the lane has remained single-family residential.

A check with the franchise utilities located within this lane indicated that the natural gas distribution main was in poor condition and scheduled for replacement. The power, telephone and cable TV utilities, however, had no work scheduled for this location.

Figure 1 shows a typical cross-section of the existing utilities within the 6-m (20-ft.) lane right-of-way. It can be readily seen that the underground profile is fully utilized. Coupled with the proximity of fences, garages, and driveways on the west side, parking

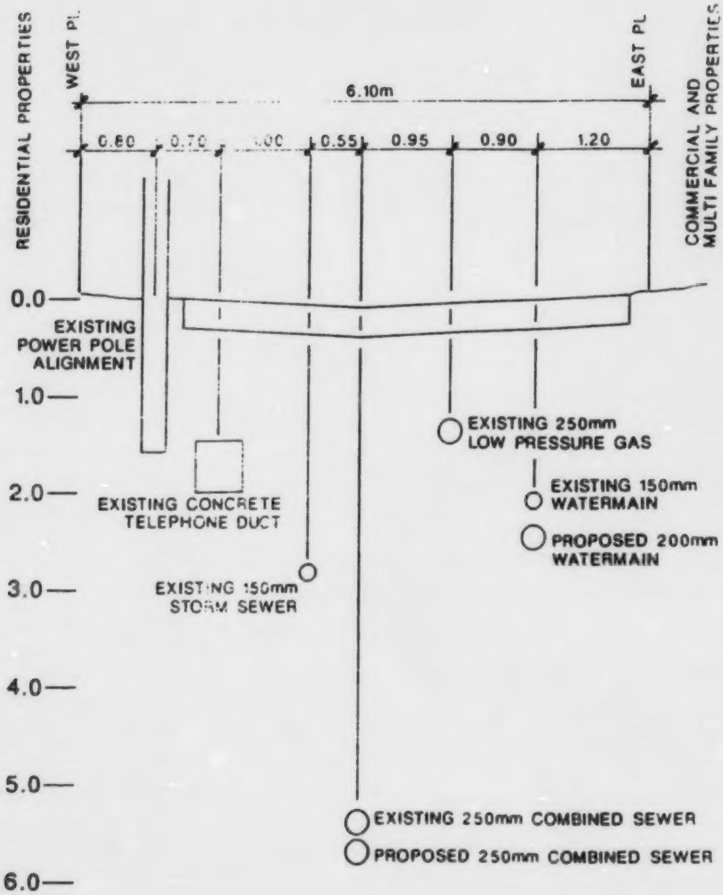
RESIDENTIAL PROPERTIES
WEST PL
6.10m
EAST PL
COMMERCIAL AND MULTI FAMILY PROPERTIES
0.80
0.70
1.00
0.55
0.95
0.90
1.20
0.0
1.0
2.0
3.0
4.0
5.0
6.0
EXISTING POWER POLE ALIGNMENT
EXISTING CONCRETE TELEPHONE DUCT
EXISTING 150mm STORM SEWER
EXISTING 250mm LOW PRESSURE GAS
EXISTING 150mm WATERMAIN
PROPOSED 200mm WATERMAIN
EXISTING 250mm COMBINED SEWER
PROPOSED 250mm COMBINED SEWER

Figure 1

TYPICAL CROSS SECTION
LANE WEST OF 124 STREET

lots and buildings on the east, and the multiple overhead wires, the difficult working conditions may be fully appreciated.

Several factors contributed to the elimination of trenchless reconstruction techniques. Foremost among these was the poor condition of the surface structure (250-mm concrete with a 50-mm asphalt cap) of the existing lane, necessitating complete surface reconstruction. With this advantage removed, the second lowest tender received (based on In situform sewer rehabilitation) was $365,000 above the lowest tender (based on traditional, open-cut methods).

With traditional, open-cut installation methods, several other system shortcomings (in addition to poor structural condition) could be remedied. These were the ability to lower the sewer invert to provide additional grade to accommodate existing capacity requirements (wet-weather flow) and to maintain minimum self-cleaning velocities (dry-weather flow). The watermain had to be lowered to below accepted frost penetration depths, and service reconnections (every 7.5 to 15.0 m) had to be replaced to each property line when lead services were encountered (30 percent of total). Poor condition of the existing gas main necessitated its replacement (this work was performed by the franchise utility in conjunction with the AMPLE reconstruction project).

During construction, all services to the adjacent properties had to be maintained and safe working conditions provided for the contractors' workers. Attempts were made to use vertical trenching with either shoring or a cage to provide protection for the men installing the new pipes. Safety to the public was also an overriding factor.

APPROACH

Toward the end of the infrastructure investigation study and during the detail design of the approved projects, a public information campaign was implemented. This included the distribution of newsletters to the entire neighbourhood, updating the status of the program, meetings with such interest groups as the Business Association and the Community League, and meetings with the general public to inform it of the study findings, upgrading proposals, and scheduling of the construction - and associated disruptions - planned for each area. The City, consultant, and contractor - all participated in this process to varying degrees.

As construction progressed and delays due to weather, poor ground conditions, scheduling work with other contractors, and unforeseen conflicts with other existing facilities were encountered, it became readily apparent that the industry standard for engineering contract administration was not adequate in this situation. The following sections highlight the main areas of action required by the consultant's reconstruction team. Due to his participation in a reconstruction project from initiation (study) to completion, the consultant must take a much more progressive role in dealing with the public and other outside organizations than in a normal new construction situation. Elements that would normally fall into the contractor's realm of responsibility and that were clearly outlined in the contract documents must now be jointly handled to minimize the disruption and inconvenience to the area residents and businesses. Cooperation and day-to-day involvement directly with the public was required by the contractor, the consultants, the City, and the franchise utility and its contractor.

COMMUNICATIONS

The importance of a good public information program cannot be overemphasized. An informed public is that much more tolerant of the disruption and inconvenience to which it will be exposed during the period of construction. This will also help minimize inquiries while the work is going. Several levels of communication should be pursued before construction. A general newsletter outlining the background and reasons for the project is a necessity. This also provides not only the opportunity to announce times and places for meetings but also a contact person and phone number, should some residents have specific questions or concerns.

Special interest groups should be identified and contacted. In this instance, we dealt with a business association representing the commercial interests, and several community groups representing the residents' interests. These meetings must occur early enough in the process, so that the issues and concerns of the groups can be addressed and acted upon, if warranted.

Be prepared to deal with issues not related to the scope of the reconstruction project. For example, in a designated architectural heritage area in the City of Edmonton, the incorporation and specification of "period"-style fire hydrants became an issue.

General public meetings provide all interested members of the general public the opportunity to view the proposed upgrading schemes and have questions answered. It should be noted that the number of interested members of the general public is substantially greater than for projects involving first-time construction. These meetings were generally divided into three parts.

The consultant team makes a presentation detailing the reason for the project (part 1) followed by a moderated question period (part 2). After this an informal mingling period allowing people to talk directly to the project team and ask specific questions about "my house" was found to be extremely beneficial (part 3).

Public communication during the construction period may require newsletters and meetings in addition to some other means of communication.

Project identification signs were erected at each end of the work site. (This has become standard practice on most construction projects over the past several years.) Its value on a reconstruction project for providing information, such as 24-hour emergency phone numbers, makes them a necessity in this instance.

Having some idea that we would be involved beyond the normal role of a consultant on this project, we allowed our team flexibility to evolve over the construction period so as to be able to respond in the most appropriate manner.

Prior to the start of construction, a "store front" location, rather than a traditional office trailer, was selected as a site office. The senior resident engineer also had a telephone installed in his vehicle. Shortly after this, personal pagers were issued to all the on-site inspectors to facilitate communication between the office and the field.

Also, at the start of construction, the contractor issued a notice explaining the work that would be going on, installation of temporary service hook-ups, and a 24-hour emergency number, should there be a problem with either a temporary service connection or some other aspect related to the construction.

A project-specific public meeting was also held at this time. This meeting dealt specifically with the project at hand. The consultant provided the background information regarding work being done and why. The contractor followed this with an explanation of how he was going to do the work, how services would be maintained, and when project completion was anticipated.

One of the most significant factors affecting the public is the time of construction. Rehabilitation/renewal work of this nature is tedious and slow, often only 10 to 15 m/day is achieved. The contractor's optimistic schedule at the start of construction led to false expectations by the residents and business community. Possibly the biggest complaint received from the public was that "I was told it was going to take so and so many weeks and it's already twice that and you're still not done".

Even the best advance planning will not eliminate the possibility of unforeseen shutdowns. The water service that was not shown on the record drawings or damage to an existing main while working on an adjacent utility may necessitate the unscheduled, and therefore unannounced, shutdown of a service while it is being repaired. When such a situation occurs, several workers should be immediately dispatched to inform all affected residents/businesses of the reason for the shutdown and the anticipated time required to place it back in service. A follow-up with principal users should be done on the restoration of service.

PUBLIC RELATIONS

For the context of this paper, public relations refers to the day-to-day contact with the residents/businesses during the construction period. The initial response on first contact often determines the subsequent course of events. Starting this in a positive manner makes follow-ups that much easier.

The greatest number of first-time contacts occurs at the site. A resident or business person approaches one of the workers with a question and if he or she receives a satisfactory answer, chances are it will end at that point. Even if the person approached doesn't know the answer, listening for a minute and then directing the person to the foreman or inspector is all that is necessary. Usually it is only a question on what is being done, or whether the damage to their driveway or fence will be fixed. (In a restricted working area like this, damage to private property is inevitable).

If the person is not satisfied with the information he or she should be referred to the office for follow-up. Due to the high profile of all the AMPLE projects, Stanley Associates Engineering Ltd. developed a "Residents Response Record" for documenting all inquiries/complaints received. These forms document the name, address, phone number, time and date, complaint or concern, action taken, and follow-up. This exercise is to maximize communication and minimize negative feedback to upper city administration and the politicians.

DAY-TO-DAY INTERACTION

The start of construction, indicated by the connection of temporary services marks the beginning of the inconvenience and disruption to routine neighbourhood life that area residents must endure for the next 1 to 2 months per block. This is not an unrealistic time frame for total upgrading of underground utilities (water, sewer, gas), lane reconstruction and restoration.

There are the immediately apparent ramifications when a lane is taken out of service. Alternate arrangements must be made for municipal and commercial garbage collection. Residents can no longer park their car in their garage. Recreational vehicles must be moved, if they are to be used during construction. Employee parking is also unavailable. Deliveries and pick-ups can no longer be accessed from the back. Different businesses have different requirements. One may want parking and access for customers, the other may have salesmen coming and going, a third might need a loading zone.

During this project there was insufficient on-street commercial and customer parking to accommodate all of the above. There was as a result a spill-over into the residential side streets, and conflicts with the residents' parking needs arose. One minor way to improve this situation is to make sure that the construction crew parks several blocks away.

Another impact on the parking situation is the need for staging areas. The contractor needs a certain amount of material at hand to do the work. Even by scheduling deliveries he will need some storage area. This is definitely not available along the length of the lane and therefore the avenues at the end of the block were used for this purpose. By requiring off-street storage, the impact of the construction on the public can be further reduced.

There are also the usual by-products of construction; noise, dust, vibration, long working hours, and weekend work. The municipal bylaws for noise levels and hours of work can be a significant production constraint.

Keeping the streets and the sidewalks clean, especially with all the parked cars, is a problem that cannot be overlooked. There is the budgeting problem because one does not know how often they will need to be cleaned as this is somewhat weather-dependent.

Construction of this nature in the middle of an existing neighbourhood is exposed to many potential safety hazards. Proper signing and fencing of excavations, material stockpiles, and equipment is essential for the safe completion of the project.

CONCLUSIONS

A project of this type and magnitude is a challenge. It is not only a technical challenge to construct the improvements under extremely difficult working conditions, including restricted working space, maintaining service of utilities being replaced and working around other "live" utilities. But it is also a challenge in public relations. This is especially true in this instance where there were single-family residential homes and commercial/multi-family interests, each with different goals.

Several necessary steps should be followed to ensure that the project will progress as smoothly as possible to completion.

1. Let the public know what you are planning to do and why. Just as important is to let it know what you are not going to do.

2. Keep the public involved. Let it know of changes. Keep it interested in the project to maintain its support.

3. Deal with complaints or inquiries immediately and in person. Let the people know that they are important and that their concerns matter.

4. Every project will be different. Be prepared to adjust your methods to deal with the specific concerns of the current project. What worked in the past may not be best for the present.

5. A clean work site is a visual statement to the neighbourhood that you care.

6. If you foresee a potential problem take steps to allow for it. If it never materializes you have lost only time. If it does come about, you are able to deal with it immediately.

7. Follow-up is essential for all complaints (once settled) and a positive public relations activity after construction is completed.

RATING AND PRIORITIZATION FOR INFRASTRUCTURE RENEWAL

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ABSTRACT

As urban neighbourhoods age, so do infrastructures which often deteriorate to the point where excessive annual maintenance or renewal is required. If a decision is made to renew the infrastructure within a given area or neighbourhood, then the most cost-effective and -efficient renewal program must be implemented.

For the defined area, an inventory and an assessment of the infrastructure components (water distribution system, sanitary and storm sewers, roadways, and streetscape) are undertaken. Components for the various sections are rated and remedial measures identified (satisfactory, rehabilitate, or replace). A database is prepared and used to establish recommended remedial measures for each component.

When the entire area is rated, the upgrading works and costs are identified and a prioritization system, which rates sections by importance, is established.

On the basis of the prioritized section, a rehabilitation program (in keeping with the allocated funding) and a staged implementation program is developed.

The rating and prioritization process targets the available funds to the most urgent components in the identified sections or areas of the neighbourhood.

RÉSUMÉ

Tout comme les quartiers urbains, les infrastructures vieillissent et se détériorent souvent au point qu'il faille effectuer une maintenance annuelle vraiment considérable, sinon les renouveler. Prendre la décision de renouveler les infrastructures d'un secteur ou d'un quartier donné, signifie qu'il faut assurer une gestion optimale, donc efficiente, des travaux de réfection.

Pour le secteur en question, il s'agit de répertorier et d'évaluer les composants des infrastructures (réseau d'alimentation en eau, égouts sanitaires et pluviaux, chaussées, l'allure des rues, pour ainsi être en mesure d'établir l'ordre de priorité du renouvellement des tronçons et de relever les mesures correctives (état satisfaisant, réfection ou remplacement). A l'aide d'une base de données mise sur pied, les autorités déterminent les mesures correctives recommandées pour chaque composant.

Après avoir déterminé l'état de tout le secteur, on caractérise les travaux d'amélioration et leurs coûts, selon leur ordre d'importance.

Le secteur prioritaire permet ensuite de mettre au point un programme de réfection (conforme aux fonds affectés) et un calendrier de mise en oeuvre progressive.

Le processus d'évaluation de l'état et d'établissement de l'ordre de priorité cible les fonds disponibles selon les travaux les plus urgents des tronçons ou zones désignées du quartier.

INTRODUCTION

In 1986, the City of Edmonton selected the Inglewood community as one area for infrastructure renewal. (The Inglewood community covers 166 hectares.) Associated Engineering Alberta Ltd. was retained by the City to provide consulting engineering services for the Inglewood neighbourhood.

The initial phase was the assessment and preliminary engineering to develop the proposed rehabilitation plan. Discussed herein is the process for assessment, costing and prioritization to allow for the rehabilitation of the worst or most urgent section with the allocated funds. The streetscape was optimized or upgraded concurrent with the rehabilitation of the utilities and roads.

BACKGROUND

Development of the Inglewood community began slowly in 1912. After World War II, there was significant expansion and development including the construction of a basic infrastructure to serve the neighbourhood.

The need to upgrade and rehabilitate much of the infrastructure in Inglewood was due to its gradual deterioration as well as the gradual redevelopment growth of the community.

The area for assessment included the following:

- The water system is made up of 21.2 km of watermain (66 percent of the pipes are cast-iron, most of which were installed before 1954).
- The drainage system consists of a sanitary system, a combined sanitary system and a storm system (total of 27.8 km of mains).
- The roadway system includes

  - 273,000 m^2 of paved carriageway,

  - 12,000 m^2 of gravel surface carriageway,

  - 34,000 m^2 of sidewalk, and

  - 46,000 lineal m^2 of curb and gutter.

DEFINITIONS	
infrastructure	primary services and amenities that include the water distribution system, the drainage system, the roadway system and the streetscape amenities
component	one primary infrastructure item, i.e., the water distribution system or the drainage system or the roadway system or the streetscape
subcomponent	one part of a component, i.e., fire hydrants, manholes, pipes, etc.
streetscape	surface features within the street right-of-way that serve to improve the quality of community environment in terms of convenience, function, character, and aesthetic appeal
repair	to restore a deteriorated or worn subcomponent through a conventional maintenance process
rehabilitate	to upgrade an existing subcomponent to extend its service life (this is not a replacement process)
replace	to eliminate an existing subcomponent from service by abandonment or removal and to construct a new similar sub-component

COMPONENT RATING METHODOLOGY

The evaluation and rating of each of the components was undertaken in two steps:

1. Establish a database. The database includes historical information, a capacity assessment, and a structural assessment.

2. Prioritize the areas of greatest need by interrogation of the established data base.

All attribute information is maintained for a specific area or street. In this assignment the smallest unit of area is one city block of street, avenue, or lane and is referred to as a section.

A section and address identification is also created for utilities located away from the street right-of-ways, and managed as though they are easements. A map and a section index was prepared for the Inglewood neighbourhood to show the section numbers with reference to street addresses.

The sections are cross-referenced to both the cadastral coordinates (City Intergraph) and database compiled for Inglewood. The sections, in turn, are then catalogued by conventional street names and addresses.

The capacity assessment is compiled on several database files concluding with a capacity rating (to be explained in more detail later) for each component. Again, this assessment is cross-referenced to sections.

Similarly the structural rating is compiled on database files and cross-referenced to sections.

By using database software, it was possible to interrogate the rating information. Not only does the interrogation process select and sort the requested information but the information can be printed or graphically referenced to the section locations on a map of the neighbourhood. Various interrogations of the information allow composite overlaying of the analyzed information on the computer terminal (colour-coded for different levels of information) for subsequent plotting.

Through this process, the remedial measures, identified on a per-section basis, are Prioritized by the rating for either structural condition or capacity.

WATER SYSTEM RATING

General

From studies done by and for the City of Edmonton approximately 15 primary causes have been identified for cast-iron watermain failure.

A database was prepared to store the rating for each section of watermain. Each main was rated under each of the criteria that are deemed to be the most important causes of failure. A rating system was established which weights each criteria numerically, such that the aggregate of all the criteria resulted in a maximum score of 100. A combined score of 100 will therefore be a perfect main; i.e., a main of non-cast-iron material installed in 1986. A combined low score will indicate a main that should have a high priority for replacement, i.e., the lower the score, the higher the priority for replacement.

Methodology

The following rating methodology was used for life expectancy:

Analysis of Historical Break Data. Each section of pipe (per block) was analyzed using database break records for 1972 to 1986. Life expectancy of a pipe was based on regression analysis similar to previous studies by the City. The slope of the regression line was identified for each main. A composite value was used for mains constructed between 1920 and 1947 and from 1957 to 1961 and a second composite value for mains constructed from 1948 to 1956.

Regression Analysis. Regression analysis was performed based on existing data as outlined above. Analysis was performed using the Lotus 1-2-3 software package. Each section of pipe (per block) was then analyzed for the projected future number of breaks per year using the defining equation for the two groups of mains as previously outlined.

'Present Worth' Analysis. Cost estimating curves were prepared for each diameter of watermain based on 1987 dollars. Cost estimating criteria for break repair was prepared for each diameter of watermain based on 1987 dollars. One or more interest and inflation rates were established for the 'present worth' analysis for pipe replacement costs using the following formula:

$$R = \text{discount rate} = \frac{r - 1}{1 + (I/100)}$$

where, $r = ?$

$I = ?$

The replacement year was then calculated by using the following formula:

$$t = t_0 + \frac{1}{A} \ln\left[\frac{\ln(1 + R)\,Cr}{N(to)\,Cb}\right]$$

where,

t = replacement year

t_0 = base year of data analysis

A = rate coefficient (previously calculated)

R = discount rate

C_r = replacement cost

C_b = repair cost for one break

$N(t_0)$ = number of breaks per 100 m of watermain in base year t_0

The above formula was developed by Shamir & Howard as documented in the May, 1979 AWWA Journal. The replacement year represents the year at which the total present value of future replacement costs plus maintenance costs reaches a minimum.

Selection of Condition Rating Criteria

As previously noted, some 15 primary causes have been identified as the cause of pipe failure. For the purpose of this evaluation the four most important of these have been identified as forming part of our rating system. They have been selected for their applicability to the Inglewood area, the availability of the required information for assessment, and other technical criteria which are readily available for review and relevant in determining the condition of a pipe. The following criteria were selected for assessment of the existing pipes:

Structural Assessment.

1. Age of Pipe - In general watermains have been assigned a life expectancy of 88 years as used by the City in depreciating its distribution system. The pipe's existing age was compared to the 88-year life expectancy and the rating calculated on its age in comparison to normal life expected.

$$\text{Score} = 25 - \frac{\text{Age of Pipe}}{88} \times 25$$

2. Pipe Material - A variety of pipe materials exist in the Inglewood area and a rating system was established for each, based on criteria available from AWWA, and past City of Edmonton experience.

Type of Pipe	Score
Cast-Iron	0
Asbestos Cement	18
Steel (coated)	25
Steel (uncoated)	10
P.V.C.	25

3. Number of Breaks - The number of breaks from 1972 to 1986 was identified for each section and the rating under these criteria will be a direct relationship to the number of breaks.

No. of Breaks/ 100 m (1972 - 84)	Score
over 5	0
4 to 5	5
3	10
2	15
1	20
none	25

4. Life Expectancy - The formula established for calculating the life expectancy of the pipe has been based on statistics of failures related to installation year because there appears to be a relationship between failure

and installation year due to installation techniques, manufacturing techniques, construction standards, etc. for certain periods.

Life Expectancy (years)	Score
0 - 10 (1997)	0
11 - 20 (2007)	5
21 - 30 (2017)	10
31 - 40 (2027)	15
41 - 50 (2037)	20
51 or more	25

The above criteria are deemed to be the most important for which information is available. Other criteria were considered but left out of the rating criteria.

1. Soil Corrosivity - Available data indicates that all of the soils in the Inglewood area are highly corrosive. No additional data exists for breaking this down on a block-by-block basis.

2. Water Pressure - The Inglewood area is relatively flat with minimal apparent pressure variations throughout, therefore this criterion was not included.

3. Water Hammer - The effects of water hammer due to pump starting/stopping, reservoir filling, hydrant and valve operations, etc. are deemed to be consistent throughout the area.

4. Depth of Pipe - No data about the depth of pipe are readily available, but generally the pipe is buried at a consistent depth, therefore this was not considered in the analysis.

5. Soil Conditions Around Pipe - Moisture content, bedding conditions, soil temperature, soil improvement - all effect the life of the pipe, however, data are not readily available for analysis.

Capacity Assessment.

1. Pipe Capacity - The pipe capacity rating was based on a comparison of the results of the ultimate water distribution model and the flow velocity within the existing system. If a 6-in. (150-mm) pipe had to be enlarged one diameter increment to an 8-in. (200-mm), pipe the capacity rating would be 50, based on equivalent pipes. For pipes less than 20-in. in diameter, a diameter increment is deemed to be 2-in. (50 mm). If a 6-in. pipe had to be enlarged two diameter increments to a 10-in. pipe the capacity rating would be 25.

EXISTING PIPE DIAMETER (mm)	PROPOSED DIAMETER (mm)	RATING SCORE
100	150	25
100	200	0
150	150	100
150	200	50
150	250	25
200	200	100
200	250	50

2. Conforming to City Standards. Conforming to city standards basically covers the requirement in the Municipal Servicing Standards that mains exceeding 200 m in length be a minimum of 200 mm in diameter. Hydrant spacing was addressed but did not influence the watermain rating. Hydrants were addressed independently of this program.

SEWER SYSTEM RATING

General

The function of the sewer system is to collect surface runoff and domestic waste within the community and convey this water to the sewage treatment plant for purification or to the North Saskatchewan River for final disposal. To fulfil this function the sewer mains require adequate capacity and acceptable structural condition.

The purpose of the proposed rating criteria is to provide an adequate and uniform assessment of the existing sewer system.

Structural Assessment

The assessment of the structural condition of combined sanitary sewer and storm sewer mains was based on the closed-circuit television (CCTV) camera inspection records and video tapes. The level of structural deterioration of specific sewer sections was defined according to the appearance of the sewer, nature of the surrounding soil (clay), and the surcharge condition under the 5-year storm frequency. Structural rating grades were assigned in accordance with the following table where 100 is a perfect structural condition:

Numeric Grade	Description of Condition	Implication
0 - 20	Missing or collapsed pipe; or deformation greater than 10 percent and cracked or fractured or broken	Collapsed or collapse is imminent
21 - 40	Structural cracking with deformation including continuous longitudinal cracks in 9, 12, and 3 o'clock position; or deformation in 3 o'clock position; or deformation fractured or broken pipes; or serious loss of pipe grade	Collapse is likely in the foreseeable future
41 - 60	Structural cracking without deformation including longitudinal/multiple cracking; or occasional fractures; or sever joint defects; minor loss of pipe grade; or badly made connections	Collapse is unlikely in the near future, but future deterioration is likely
61 - 80	Minor defects including circumferential cracking; or moderate joint defects; or root intrusion; or encrustation; or poor service connections	Risk of minor collapse in the short term with the potential for further deterioration
81 - 100	No significant structural defects	Acceptable structural condition

Capacity Assessment

Hydraulic (capacity) assessment of the sewer system was based on the results of computer modelling for a 5-year design storm. The computer printouts showed the relationship between the capacity (design flow) of the existing sewer, the maximum computed flows, and the degree of surcharge, where applicable.

Surcharges in the sewer system increase the risk of damages due to basement and street flooding and accelerate the structural deterioration of defective sewer sections. Therefore, to provide an adequate and uniform hydraulic grading of the sewer system, the following criteria was established:

Numeric Grade	Description of Defect	Implication
0 - 20	Basement flooding due to excessive surcharge during rainstorms (5-year and greater frequency); street flooding during rainstorms (2-year and greater frequency)	Damages to private properties, unhappy residents and possible litigation
21 - 40	Street flooding during rainstorms; damages and accidents (5-year and greater frequency)	Inconveniences to traffic, possible property damage
41 - 60	Excessive surcharge condition (water level rises more than 1.5 m below ground surface)	Deterioration of sewer mains at defective pipes and joints
61 - 80	Moderate surcharge condition (water level rises less than 1.5 m below ground surface)	Deterioration of joints and poor connection
81 - 100	Adequate capacity (no surcharge)	Acceptable hydraulic performance

ROADWAY RATING

Structural Assessment

Carriageways. Establishment of structural rating for carriageways is based on the American Public Works Association PAVER program.

Whereas the full program analyzes a total of 21 surface distress factors, for this assignment this number has been limited to the following nine factors grouped under cracking stresses and deformation stresses. Cracking Stress: alligator, map, longitudinal and transverse, and edge. Deformation Stresses: bleeding, distortion, rutting, rippling, and ravelling.

Each section of roadway was visually inspected. For each distress, a low (L), medium (M), or high (H) grade, depending on the severity encountered, is assigned. The information is entered onto the Condition Survey Form (see sample). The percentage area (of the total carriageway area in that section) is calculated for each value and a "deduct value" calculated.

Through empirical formulas developed in the PAVER program, a corrected "deduct value" is obtained which, when subtracted from 100, gave the visual structural rating of the carriageway.

The above mathematical process was calculated by computer. Input was from the Condition Survey Form with only the "EXTENT" and "TOTAL AREA" numbers inputted by field staff.

Curbs, Gutters, and Sidewalks

Structural rating methods for curbs, gutters, and sidewalks were adopted from the City of Edmonton procedure.

Through visual inspection, structural defects and their severity were identified. A numeric rating on a scale of 0 to 100 is assigned for each category, namely 100 = excellent, 60 = fair, 20 = poor.

The categories for curbs, gutters, and sidewalks are distortion (vertical, horizontal, or rotational movements), curb height, cracking, and spalling.

A category particular to curbs and gutters is curb height where numbers are assigned for varying face of curb heights.

The worst condition of the section governed the rating assigned. The rating for curb and gutter on both sides of the carriageway are averaged to derive the rating for the section.

For sidewalks, sidewalk crossfall and sidewalk drainage problem are particular categories.

No number was assigned for sidewalk drainage problems, but they were noted for reference.

An overall structural rating is attained by averaging the assigned numbers for the first four factors.

The sidewalk ratings for a section are averaged to derive the rating per section.

Capacity Assessment

Each city roadway is classified according to a standard. Each classification has its own standard width and standard pavement structure.

Compliance of the actual carriageway, curb and gutter, and sidewalk to the City of Edmonton roadway standards were assessed and rated as follows:

Deviation (%) from standard	Rating
0 - 5%	100
5 - 10%	80
10 - 20%	60
20 - 30%	40
>30%	20

PRIORITIZATION

Method

The remedial measures for each component are prioritized in the order of the lowest to the highest rating for either structural condition or adequate capacity. Having identified the prioritized program then the synthesis of all the components can be undertaken by

1. filtering the sections to identify those that have the most components with the most urgent need for remedial work,
2. identifying critical sections and giving priority to them, and
3. identifying sections that have remedial needs independent of other components.

The synthesis used the computers capability to "select and sort" the information out of the database. The various results may be plotted or viewed on the terminal screen.

To prioritize the various sections the importance of undertaking remedial measures was "scored" for each of the seven components - water, sanitary sewer, storm sewer, curb and gutter, carriageway, sidewalk, and streetscape amenities - within each section.

Through discussion with the City and with residents in the community the seven components were rated from most critical to least critical with the maximum possible rating score (highest importance) listed beside it.

Component	Maximum Score
Water	20
Sanitary Sewer	20
Storm Sewer	10
Carriageway	10
Sidewalk	3
Curb & Gutter	2
Streetscape	5
TOTAL	70

In each component, a value up to the maximum score was assigned depending on its structural or capacity rating.

Water Importance Score

The importance of undertaking the remedial measures within the section was based on the lower of either the structural or capacity rating.

1. There is no proposed water remedial work in the section.

1.	no existing pipe -	0
2.	existing pipe rating between 81 and 100 -	2
3.	existing pipe rating between 61 and 80 -	4

    4. existing pipe rating between 51 and 60 - 6

2. There is proposed water remedial work within the section.

    1. pipe crossing the section is being replaced - 8

    2. pipe crossing the section is being replaced and pipe will have a new cross-connection - 10

    3. pipe to be abandoned - 12

    4. existing main rating from 41 to 50 - 16

    5. existing main rating 21 to 40 - 18

    6. new pipe or existing main rating from 0 to 20 - 20

Sanitary Sewer Importance Score

The importance of undertaking the remedial measures within the "section" was based on the lower of either the structural or capacity rating.

1. There is no proposed sanitary remedial work in the section.

    1. no existing main - 0

    2. sanitary line with no rating - 2

    3. existing main rating between 81 and 100 - 4

    4. existing main rating between 61 and 80 - 6

    5. existing main rating between 41 and 60 - 8

2 There is proposed sanitary remedial work within the section.

    1. CB reconnection only - 12

    2. existing main rating between 21 and 40 - 14

    3. existing main rating between 0 and 20 - 20

Storm Sewer Importance Score

The importance of undertaking the remedial measures within the section was based on the lower of either the structural or capacity rating.

1. There is no proposed storm remedial work in section.
    1. no existing main - 0
    2. existing main rating between 81 and 100 - 1
    3. existing main rating between 61 and 80 - 2
    4. existing main rating between 41 and 60 - 3
2. There is proposed storm remedial work in section.
    1. new storm sewer; - 7
    2. existing main rating between 41 and 60 - 8
    3. existing main rating between 21 and 40 - 9
    4. existing main rating between 0 and 20 - 10

Carriageway Importance Score

The importance of undertaking the remedial measure within the section was based on the structural rating.

- road with rating from 0 to 20 - 10
- lane with rating from 0 to 20 - 9
- road with rating from 21 to 40 - 8
- lane with rating from 21 to 40 - 7
- road with rating from 41 to 60 - 6
- lane with rating from 41 to 60 - 5

- road and lane with rating from 61 to 80;- 4
- road and lane with rating from 81 to 100 - 3
- gravel roads and lanes - 2
- roads and lanes with no rating - 1
- easements - 0
- no curbs - 0

Curb and Gutter, Sidewalk Importance Score

The importance of undertaking the remedial measure within a section was based on the structural rating.

1. Curb and Gutter
    1. rating from 0 to 59 - 2
    2. rating from 60 to 100 - 1
    3. no curbs - 0
2. Sidewalk
    1. rating from 0 to 40 - 3
    2. rating from 41 to 59 - 2
    3. rating from 60 to 100 - 1
    4. no sidewalk - 0

Streetscape Amenities Importance Score

The importance of undertaking remedial measures or proposed new streetscape amenities within the section was established.

- combination of trees, pararamp required - 5

- minor pararamp only required - 3

- no work required - 0

Prioritization

The importance score of each component identified on a per-section basis was tabulated to arrive at an aggregate importance score for each section. The sections were prioritized according to the importance score.

Those sections that had a low assessment rating for structural or capacity components would have a high importance score. When several components within a section have a high importance score then the aggregate importance score of the section identifies the importance relative to all others.

In concert with assessment ratings and importance scoring, a relational database was maintained to tabulate the cost for the proposed remedial measures. Thus, when a priority listing is examined based on the importance score per section, the costs per section and aggregate cost for the remedial works for sections or group of sections can also be examined with the highest score.

PROGRAM DEVELOPMENT

Once having a prioritized listing of sections requiring rehabilitation and a related cost database has been generated, the next step is to define the size of the proposed remedial program, the time frame, and the allocated funds.

If the proposed program is limited, then the sections with the highest importance scores would be given priority for implementation.

If the proposed program is of 2- or 3-years duration, then the program can be staged and optimized by recognizing the logistics of confining and completing the work in a specific area, scheduling construction to control traffic, maintaining access to properties, maintaining service, and mitigating disturbances and inconvenience.

As the program is developed, the related cost database provides a guide of the program cost. This allows the planner to try several scenarios before finalizing a recommended program.

CONCLUSION

The assessment rating focuses on the structural and capacity assessment of the various infrastructure components. As the assessment rating was developed a recommended remedial works plan was identified and costed.

To prioritize the various sections identified for remedial works, the importance score provided a means of identifying the most urgent sections. The importance score already looked after the established criteria.

With the prioritized list of sections recommended for remedial work together with the related cost estimates, a program can be developed that gives preference to the sections with the greatest need for remedial measures.

The rating and prioritization process provides a technical system to select priority sections and an objective, quantitative approach to managing a renewal program.

INFRASTRUCTURE UPGRADING IN A DYNAMIC GROWTH ENVIRONMENT: YELLOWKNIFE, N.W.T.

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ABSTRACT

The City of Yellowknife - the capital of Canada's Northwest Territories - is experiencing a period of growth unprecedented in its history. This tremendous growth is occurring simultaneously with badly decaying infrastructure and makes for particularly challenging times from a planning and engineering perspective.

It has been necessary to exercise management of limited human, financial and physical resources to achieve this upgrading, while at the same time accommodating growth.

The City's population has been increasing by approximately 10 percent annually for the past 3 years. Private land development has increased tenfold over the past 2 years, with similar projections forecast for the near term.

Development permits issued have almost doubled over the past 3 years. When the value of municipal building permits is analyzed on a per capita basis, the City shows one of the most significant rates of growth in the country.

Existing infrastructure is now taxed to capacity. An upgrading program initiated in 1985 to replace aging infrastructure has been expanded to accommodate this greatly increased rate of growth.

RÉSUMÉ

Yellowknife, capitale des Territoires du Nord-Ouest, connaît actuellement la meilleure période d'expansion de son histoire. Le simple fait que cette formidable

croissance coïncide avec l'importante dégradation de ses infrastructures laisse entrevoir un défi de taille du point de vue de la planification et du génie.

Il a fallu gérer judicieusement les ressources humaines, financières et physiques limitées pour réaliser ces travaux d'amélioration tout en tenant compte de la croissance.

La population de la municipalité accuse une hausse annuelle d'environ 10 p. 100 depuis trois ans. L'aménagement de terrains du secteur privé s'est multiplié par dix au cours des deux dernières années et l'on établit des prévisions semblables pour les prochaines années.

Le nombre de permis d'aménager délivrés a pratiquement doublé lors des trois dernières années. En ramenant la valeur des permis de construire muncipaux per capital, la ville affiche l'un des meilleurs taux de croissance au pays.

Les infrastructures existantes ont maintenant atteint leur point de saturation. La portée du programme de réfection amorcé en 1985 dans le but de remplacer des infrastructures vieillissantes a été étendue pour soutenir ce fort taux de croissance.

INTRODUCTION

The initial phase of the works undertaken in 1985 essentially replaced the existing facilities with insulated, ductile-iron watermains, uninsulated, ductile-iron sewer mains, and pre-cast concrete manholes. The mains were sized to accommodate the proposed levels of growth. This upgrading program would not have been possible without the 80 percent funding contribution from the Government of the Northwest Territories.

Despite experiencing difficulties in providing the City with adequate levels of funding to undertake the upgrading program, the territorial government ended last year with a major surplus of $57 million.

The City's program was ambitious. A 3-phase program costing approximately $4 million to $5 million a year was originally decided upon. The initial phase, completed in 1985, exceeded $4 million. Material and manpower resources were taxed to capacity. The following phases, completed in 1987 and 1988, were significantly smaller: approximately $1.5 million a year. The magnitude of the project remains consistent; by reducing the yearly projects, we are just taking longer to complete the work. We are pleased to report that we are progressing slowly but surely.

FOLLOW-UP TO FIRST PHASE OF THE PROJECT

The completion of the first phase of the project resulted in a number of recommendations to improve and streamline future phases.

The construction phase of the initial component of the project revealed a system which was in a state far worse than had been envisaged. Instead of the 1-year interval allowed for between phases to ensure that each phase was completed before the next one is initiated, yearly programs have been scheduled.

The original water system, installed in the late 1940s, incorporated a system of supply and return mains. Circulation in the water services to individual homes was maintained by the pressure differential in the mains themselves. Where the twin water pipe systems in the downtown have reached the end of their useful life and have been replaced, a single replacement pipe has often been installed. There is then no circulation in the double water service into the property. For 2-year line services, circulation pumps have been adopted as standard practice.

With the installation of a single main system, alternative methods of freeze protection were explored. Such single services are often electrically heat-traced, as a freeze prevention method. A problem arises when heat tapes burn out in time. Aqua-Flo devices became available in 1985 as a cost-effective solution to such retrofit situations. Aqua-Flo devices allow water to bleed into a tank. When the tank is full, the water in the tank is pumped back into the main. This provides regular movement of water in the service pipe, regardless of the actual amount of water consumed in the building. Thus, water is not allowed to remain stagnant in the water service pipe long enough for it to freeze. Until the introduction of Aqua-Flo units, a burnt-out heat trace on single services meant either expensive excavation and repair (the owner's cost) or water bleeding (the City's cost, at least in the first year of bleeding). Aqua-Flo units are being installed as part of the water and sewer replacement program, where it is cost-effective to do so. In the 1988 program, approximately 50 circulation pumps and 15 Aqua-Flos were installed.

Because of the high cost of heating the city's potable water, every effort is made to eliminate uncontrolled water bleeding into the sewers.

Our original program envisaged only the upgrading of the sewer system. The current program has included the replacement of uninsulated, cast-iron watermains with heavily insulated, ductile-iron mains and complete reconstruction of affected roadways. This decision has proved to be very beneficial from an operations and maintenance point of view. With the raw water supply temperature hovering only slightly above 0°C during the winter, the infusion of vast quantities of heat into our potable water becomes a necessity. The decision made in the 1940s to install uninsulated water mains has cost us dearly for four decades. The installation of insulated mains has had a rather noticeable effect on our heating costs and our ability to ensure a continuous flow of potable water through our distribution system throughout the year.

In addition to improving the technology used in our replacement program, the manner of tendering the works was closely examined.

Given the city's location, outside the concentration of major civil contractors, a pre-qualification process was utilized to ensure that the contractors bidding were, in fact, qualified to undertake the work. Prerequisites for becoming a pre-qualified contractor were primarily financial with an assessment of prior experience in similar upgrading projects. The pre-qualification process worked well; yet regrettably, the obvious was overlooked. The contractors' base in Canada has only a limited exposure to major infrastructure upgrading projects. The contractors' base in the Northwest Territories had none, simply because this type of project had never been undertaken before. A major southern civil engineering contractor was chosen for the initial phase of our upgrading project.

Although this contractor had a record of past accomplishments in similar projects, the difficult and previously unencountered site conditions, such as permafrost and extensive ground ice, proved daunting. While the work appeared to be accomplished with only minor deficiencies, the passage of several months added many more problems. Significant surficial subsidence of mains in ice-rich areas has prompted a re-evaluation of design and construction methodology.

As a result of the degree of problems encountered from the 1985 upgrading work, both the civil engineering site contractor and the design engineer involved were sued by the City.

LOOKING FORWARD

Amidst the bustle of infrastructure conferences, detailed design for future phases, operation of our system, and even ongoing litigation, one thing remains constant: the continuing need to upgrade the central servicing component of our city.

The Department of Public Works and Engineering has prepared detailed servicing standards to assist developers, contractors, consultants, homeowners, and builders in their endeavours to develop and provide servicing within the city. These standards reflect historical records and current policies and procedures of the City, and they are being continuously updated and expanded with an aim to ensuring the implementation of good design practices in land development and servicing. The servicing standards now form an integral component of signed agreements for private land development and ensure a degree of standardization of all city servicing.

Perhaps the most consistent problem we have faced throughout the infrastructure upgrading program is that of funding. A commitment for 80 percent of the costs of the program from the Government of the Northwest Territories allowed the upgrading to proceed. This level of funding has proven to be an onerous burden for the government. It has been difficult to provide the city with the required funds for infrastructure upgrading when sufficient funds do not exist for the installation of even the most basic services in some communities in the Northwest Territories. The commitment remains, yet the actual cash flow is lacking. The Government of the Northwest Territories has been unable to keep its commitment for the 1988 construction year and has also been unable to budget funds for the construction proposed for 1989. The immediacy of the upgrading has resulted in debentures being approved by the City's ratepayers and the "borrowing" of funds from other City programs, such as the land development fund.

In one way, the City of Yellowknife is more fortunate than most southern municipalities. There is at least a commitment from a senior level of government to assume the lion's share of the funding. This commitment has been instrumental in allowing our city's infrastructure upgrading program to proceed. There has, however, been an ongoing struggle to ensure that this commitment is met.

In an effort to lessen the reliance on the requirement for major infusions of capital from sources which are increasingly unwilling to provide funds, we have instituted an infrastructure upgrading reserve fund. A surcharge will be assessed on each monthly municipal water bill in an effort to build up sufficient reserves to undertake future infrastructure upgrading. Our current approach is to begin planning for the ultimate replacement of our infrastructure from the moment it is purchased or constructed. While funding may be the most consistent problem we have faced, the major challenge before us is to complete this vitally important infrastructure upgrading work in an atmosphere of overwhelming growth. For the past 2 years, municipal building permits have averaged in excess of $50 million a year. With construction of this magnitude, the demands on a limited manpower and equipment base are substantial.

NORTHERN MUNICIPAL WORKS

Concurrent with the infrastructure upgrading program, the day-to-day operations and maintenance activities must still be accomplished. The duties of public works crews in our city certainly do not differ materially from those in southern municipalities. A consistently high level of service to a population of approximately 14,000 must be maintained in all facets of water supply, sewage and waste disposal, roads, sidewalks, drainage, etc.

The Department of Public Works and Engineering delivers programs in two areas: the Works Division and the Engineering Division. The Works Division carries out the operations and maintenance programs which cover the delivery of the basic municipal services, such as piped or trucked sewage disposal and water to all residents, garbage collection, maintenance and repair of the City's roadways and sidewalks, and the provision of a vehicle service to all City departments. The Engineering Division delivers the City's capital works programs which include major construction under the water and sanitation program (water treatment and sewage disposal facilities), the roads and sidewalks program (new road construction, paving, and concrete work), the land development program, and major and minor capital works for other City departments. Both the operations program and the maintenance program and the engineering program are delivered in accordance with the policies, practices, and budgetary guidelines established by city council.

In order to provide these services, the department must construct, maintain, repair, and operate a network of watermains, sewers, roadways and associated facilities, and equipment with a total replacement value in excess of $150 million. The department provides service to the public through its operations and maintenance and capital works programs with a total staff complement of 36 employees.

The particular challenge facing our City's public works crews is to maintain this high level of service in an environment of tremendous growth. A pre-dawn to after-dusk level of activity is required of our City's public works crews to maintain a consistently high degree of public service. This high level of activity is carried out in a harsh and unforgiving environment. During the November through February period, temperatures are regularly colder than -40°C. During these "cold snaps", the provision of municipal services must, of course, continue. Temperature and pressure checks are continually made of the entire distribution system. For a period of several weeks prior to and after the winter solstice on 21 December, daylight hours are limited. Many daily activities dealing with the provision of services are carried out during darkness.

PLANNING

During this period of explosive growth, overall planning becomes extremely important. The tendency is to plan for the immediate problem and let everything else drop. A heavy emphasis has been placed on the overall approach to planning in our City. We have recognized that our infrastructure has limitations and we are planning around this. In order to put planning in perspective in a Northwest Territories and Yellowknife context, the following overview is offered. The urban planning process in Yellowknife is, in theory at least, comparable to that of southern Canadian communities. The Planning Act for the Northwest Territories establishes the hierarchy of planning instruments, these being the General Plan, Development Scheme and Zoning Bylaw, and it details the manner in which they are to be prepared, implemented, and monitored.

Differences in Planning Process

Although the acts and regulations tend to be less complex than those in the South, their thrust is similar. In practice, the planning process for the City of Yellowknife varies considerably from that in most southern jurisdictions, especially in the area of land development. There are a variety of interrelated reasons for this which might be summarized as follows.

Land Tenure. Most undeveloped lands in the City are under the jurisdiction of the Government of the Northwest Territories and are only turned over to the municipality upon proven evidence of need, based on adequate planning and forecasting of demand. Lands cannot be acquired directly from the territorial government by the private sector. Any applications for land from the private sector must be made through the municipality.

The availability of land is therefore controlled by the government and can be severely limited if the municipality has not demonstrated the amount, type, and location of lands required, complete with a well thought-out plan for their use, well in advance of need.

Another critical factor in land tenure is the ongoing native land claims. At the claimants' request, the government has adopted a "lease-only" policy and will only transfer clear title to the municipality in areas where the claimants have not registered a prior interest. The claimants are now actively involved in land selection within the municipality, creating a degree of uncertainty from a development perspective.

Land Development. Until very recently, the City was the sole developer of residential, commercial, and industrial lands and, as such, has been in the position of legislating and monitoring its own activities. It can be most challenging to prepare and manage objective plans for areas in which the municipality has a direct interest, both politically and financially.

In recent years, the City has begun to move towards private land development. Although this allows the introduction of additional resources into the land development process, it also necessitates the preparation of new policies and procedures which must be acceptable at both the municipal and territorial levels of government.

Period of Transition. The community is rapidly evolving from a small, isolated, relatively unsophisticated resource town in Canada's northern frontier to a larger, more complex, and faster-paced urban environment linked politically, financially, and culturally with the rest of the country. This period of transition involves a change in views, values, and goals which can occur at a different rate and to a different degree for the various people, groups and institutions which make up the community. The result, in terms of planning and land development, is a lack, at times, not only of a clear, shared sense of where the City is or should be going but also of the appropriate means to get there.

Rapid Growth. The city is experiencing a period of unprecedented growth and development. In the last 3 years, development permits issued have almost doubled, private land development has increased tenfold, and the annual rate of population growth has approached 10 percent. This has placed extreme pressure on both the political and administrative arms of the municipality to react quickly, efficiently, and wisely to new and increased demands on human, financial, and physical resources. It becomes particularly difficult to stretch resources, while at the same time maintaining the balance required between long-range planning and more immediate short-term requirements.

The very rapid growth has necessitated that the City consider development in special interest locations such as the Niven Lake and Tin Can Hill areas. Recreation and environmental groups have expressed concern over this possibility and there have been ongoing debates regarding the need for development in these areas. This is really the first time that the City has encountered any opposition to its development plans.

Diversity in Values. The City of Yellowknife is a community of extremes, not only in climate but in the makeup of its residents. The overall profile is one of a relatively young, well-educated population with a high disposable income and high birth rate. This is, however, a generalization. A closer examination reveals a variety of groups of people, including the original native inhabitants with their traditional values, residents who have lived in the City for several decades and call the City their home, the "middle class" who tend to expect the same services, facilities, and attitudes they were accustomed to in the South, and finally a group of people from all walks of life who value and wish to preserve the social, cultural, and environmental aspects of the North which make it unique.

The diversity of peoples and corresponding values, which is evident in any community, is thus amplified in a city such as Yellowknife. The process of planning for its future is often a process of discovery which must balance traditional planning theory and practice with an appreciation of the North and its inhabitants.

Requirement for Close Coordination

The five factors outlined above (land use, land development, period of transition, rapid growth, and diversity of values) may not seem unique when considered separately. When combined, however, they contribute to a situation which is very different from that in many southern communities. For example, in 1988, the City found itself in the position of concurrently planning, rezoning, and subdividing lands for private development over an extremely short (8-month) period of time. A similar scenario is unfolding in 1989, and the amount of land involved has increased dramatically each time. At the same time, the City continues its own industrial land development program and its long-range planning program (including preparation of a new general plan, review of the Zoning Bylaw and initiation of secondary planning for both new and established areas of the city).

All these activities require close coordination between the planning, engineering, and finance departments of the City as well as with council, the territorial government, and the public. All these groups have their own heavy agendas as well, and time becomes very precious.

In summary, the urban planning process in the City of Yellowknife is an evolutionary process which tends to blend traditional planning theory and practice with a more pragmatic view of the community and its people, and this is being undertaken within severe time, physical, and financial constraints .

CONCLUSION

Yellowknife is somewhat distant from the mainstream of Canadian infrastructure upgrading activity, yet our problems and concerns are just as immediate and pressing as those in southern Canada. A failed watermain, an overloaded sewer main, or a poorly maintained public building all have potentially the same consequences north of the 60th parallel as they would in other areas of Canada.

In Yellowknife, we are fortunate that funding is committed and planning can take place. The replacement and upgrading of our City's water and sewer infrastructure has always been a priority. With such a drastic increase in levels of growth over the past 2 years, the upgrading of our basic infrastructure becomes even more crucial. In order that massive city centre development can be allowed to continue, the basic infrastructure must be upgraded and replaced in a timely manner.

REGINA - PAST, PRESENT, AND FUTURE

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ABSTRACT

The City of Regina started the rehabilitation program for its infrastructure in 1979 with funding available through federal and provincial programs, and through a charge-back scheme applied to owners of property near the construction work. When the federal grants were discontinued, the City absorbed the financial shortfall. Yet the funding for infrastructure shows that about $170 million are necessary for repairs and upgrading over the next 10 years.

RÉSUMÉ

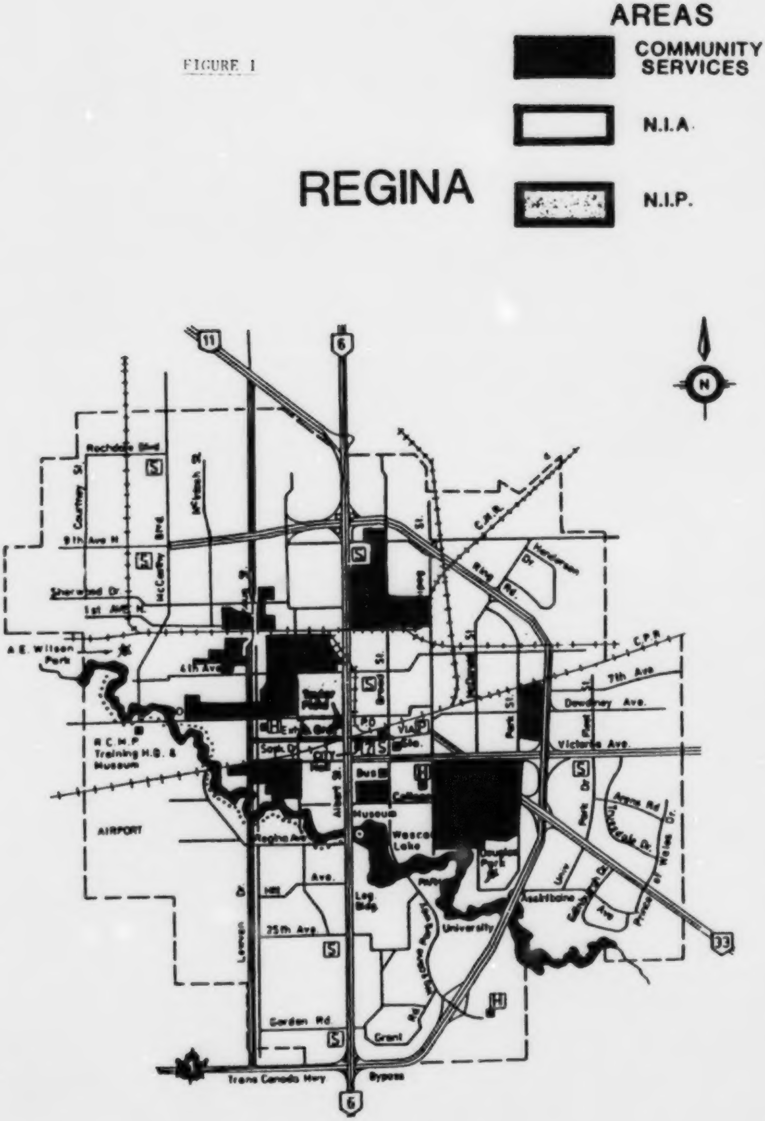
En 1979, Regina mettait en branle son programme de réfection de ses infrastructures, financé en vertu de programmes fédéral et provincial et par l'imputation des charges des travaux aux propriétaires fonciers situés à proximité des lieux. Lorsque le gouvernement a cessé de verser les subventions, la municipalité a dû absorber le manque à gagner. Pourtant, le financement des infrastructures montre qu'une somme d'environ 170 millions de dollars est requise pour effectuer les travaux de réparation et d'amélioration au cours des 10 prochaines années.

INTRODUCTION

Regina is a city of 175,000 inhabitants. It covers an area of approximately 110 km^2 and is built on expansive clays (see Figure 1).

More than 80 years ago, men started to put sewer and water lines in the ground to provide services for the several thousands of people who came to live there. And they started to pave streets, build sidewalks and bridges, and they have been doing it ever since, and will continue to do so.

FIGURE 1


AREAS
COMMUNITY SERVICES
N.I.A.
REGINA
N.I.P.
11
6
N
Rochdale Blvd
Courtney St.
McIntosh St.
9th Ave N
McCarthy Blvd
Sherwood Dr.
1st Ave N
A.E. Wilson Park
6th Ave
Taylor Field
C.N.R.
Ring Rd.
Henderson Dr.
Broad St.
C.P.R.
7th Ave.
Dewdney Ave.
Park St.
Victoria Ave.
R.C.M.P. Training H.Q. & Museum
Albert St.
Bus
College
Museum
Wascana Lake
AIRPORT
Regina Ave.
Lewvan Dr.
Hill Ave.
Leg. Bldg.
25th Ave.
University
Assiniboine Ave.
Prince of Wales Dr.
Truesdale Dr.
Univ. Park Dr.
Douglas Park
33
Garden Rd.
Grant Rd.
Trans Canada Hwy
Bypass
1

REGINA IN THE 1970s

However, in the mid-1970s, people in our industry began to realize that much of the work that had been previously done needed reconditioning. And not only that, we began to understand that, unless we were prepared to supply sufficient funds toward comprehensive maintenance programs, we would find ourselves in ongoing renewal programs with major highs and lows in activity as our facilities continued to age.

The state of deterioration of the urban infrastructure reached national prominence with the publication of F.C.M.'s report in 1984. In Regina, the results of our findings were far less newsworthy, but equally as significant to our city.

In 1978, a few years prior to the F.C.M. study initiative, the City of Regina began a condition study of its own, constituting the first step of the renewal program, that is, in place today.

We started with a survey of all of the sidewalks followed by a watermain performance study. The results of this survey were rather startling and quickly led to a review of other services, such as storm and domestic sewers, catch basins, and manholes.

On completion, when an initial cost of $33 million to alleviate the deficiencies in the infrastructure was presented, it took some time for our decision-makers to come to grips with the problems. Fortunately they did and our initial program was started in 1979. It involved renewal programs for cast-iron watermains and concrete walks and curbs. These two had to be combined since, in many instances, the location of the watermains in the street rights-of-way was such that the water line could not be exposed and renewed without removing the walk located above or immediately adjacent to it.

This program started out as a 15-year renewal program, but unfortunately, with recent economic cutbacks it had to be extended. We believe that we have approximately 12 years left to complete this program.

The initial concept of our program, which we still hold to be true, is that the renewal program aims to bring the infrastructure back to a reasonable condition and standard, so that on completion, the upgrading and maintenance requirements will be funded out of normal maintenance budgets and sufficient in size to avoid accumulations of large backlogs of deteriorated systems.

Budgets, as they have always been, were of concern in 1978 and led to the consideration of a number of options for funding the renewal program. Two basic facts emerged that set the stage for our financial program:

1. At the time, there were federally funded programs that could be applied to infrastructure renewal: the Neighbourhood Improvement Program (NIP) and community service programs and funds.
2. Local improvement programs had been used successfully in the past to partially fund renewal programs for walks and watermains.

The local improvement program, as authorized under the Provincial Local Improvements Act, allows the municipality to charge back at least a portion of the cost of rehabilitating watermains, sewers, and walks and curbs to the owners of property abutting the work. In the case of Regina, the charge-back rate is set at the equivalent cost of installing that facility in a new subdivision. Depending on the nature of the work, the percentage paid by the property owners may vary from 30 to 50 percent of the total cost. Specific requirements for public advertising and support of the projects must be followed. If a majority of owners abutting the project oppose the works by petition, the local improvement method of funding cannot proceed.

One of our initial concerns was that if the local improvements were exclusively used for the renewal program, the older low-income areas of the city, areas in most need of replacement, would petition against the works and the program would stall.

To counteract this possibility and to provide an incentive to the property owner, it was decided to use federal NIP money to offer reductions in assessments in selected NIP and community services areas of the city. In such areas, the homeowner assessment was reduced a further 50 percent.

REGINA IN THE 1980s

This was the financial program put in place in 1979. Unfortunately, shortly after the program began, the economic slowdown of the 1980s began and subsequently, the federal funding programs were discontinued. Our council then took another major decision: to substitute City money for the lost federal grants. That commitment to reduced assessments is still supported today.

Despite these incentives, property owners still petition against 10 to 15 percent of the advertised programs. To compensate for this, our practise has been to over-advertise by about 30 to 40 percent of planned budget. In this way, we can be assured of sufficient locations to satisfy our budgeted amounts.

This initial program quickly led to other events. In 1980, the City purchased a closed-circuit TV camera to allow a survey of the condition of storm and sanitary sewers.

The results of the ensuing camera work were a pleasant surprise. With the exception of isolated spots, our sewers were in excellent condition.

We now had the necessary information that allowed us to rebuild walks, curbs, and waterlines and to incorporate occasional sewer work to give us an economical and efficient renewal program.

An unpleasant surprise followed on the heels of the camera program. As you might expect, we started poking into manholes and catch basins and leads, and found them generally below standard condition. Through reviews of manholes and catch basins, we gained enough knowledge to allow us to set appropriate budget allowances for a necessary part of our renewal program.

In 1983, we completed a city-wide assessment of pavement conditions of arterial roads. This study was the basis of a pavement management study completed and approved in 1985. We found that in order for us to reach a point where pavement structures were no longer in a state of decline would require an increase in funding of approximately 10 percent a year plus inflation for at least the next 10 years. In approving these studies, our council took another major decision. Being aware of the F.C.M. report and funding initiatives, the City resolved not to change its funding objectives even if the provincial and federal governments could be convinced to support F.C.M.'s funding plan. This is significant in that, given matching funds, we could triple the size of our programs.

Our infrastructure review had not finished yet. For a prairie city with one small creek running through it, we have some 53 bridges and weir structures. So, in 1988, we completed a structure condition survey which predictably followed the trends of all our other findings - we needed funding in excess of $7.2 million over the next 10 years to recondition these structures.

The studies just described were completed over a 9-year period. Two other reviews have been added to our growing list of requirements. Regina has a considerable number of improved gravel lanes, servicing our older grid pattern subdivisions. Both users and the City would like a better level of service - that provided by paved lanes. The cost for this program was determined to be roughly $20 million.

The second review examined the level of service provided by our storm sewer system. The prairies are subjected to infrequent high-intensity rainfalls, sometimes in the order of 1-in-100-year events. The older storm sewer systems have been found to lack the necessary capacity and to be well below present-day standards. To provide a reasonable level of service, say, to 1-in-5-year events, may cost as much as $55 million.

We have actually started to work on these last two programs as well as all the others. The lane paving improvement is based on a local improvement program with 60 percent of the cost borne by the abutting owners and 40 percent by the City. 1989 will be our first year and our expectations are that residents will be reluctant to support the program.

The storm water system improvements are, with sufficient advanced planning, incorporated into our street and walk renewal programs. The design of the improvement is the easy part, the financial plan is the real problem.

The combined costs of all programs add up to about $140 million. Another $30 million may be added to accommodate all of the storm sewer upgrading (see Table 1).

In terms of our present trend of spending, in constant 1985 dollars the amount required to meet the standard in 10 years is $24.6 million; about $7.5 million has actually been spent to date for pavement (see Figure 2). The result is a projected $17 million shortfall over the 10-year period. At current levels of spending, the pavement condition can be expected to fall well below acceptable standards by 1995.

Figure 3 compares present expenditures with projected needs for the past year, 1988. Regina is falling behind, especially in the area of pavement management.

One of the identifiable benefits derived from this program is the drop in watermain breaks because of a corresponding drop in cast-iron pipe (from 119.6 to 47.2 km) between 1979 and 1987 (see Figure 4).

Table 1
Infrastructure Renewal - Capital Projects
1989

Project	Total Amount Deteriorated Infrastructure 1989 ($m)	Approx. Yearly Average Budget Need 1989 ($m) (1)	1989 Budget
- Sidewalks, Curb and Gutter	28.5	2.85	2.674
- Centre Median Curb	4.37	0.375	0.250
- Pavement	25.17	4.894 (2)	4.478
- Watermain Renewal	13.2	1.65	1.643
- Sanitary Sewers Renewal	2.6	0.326	0.864
- Catch Basin Cross Connected	1.56	0.195	0.203
- Storm Sewer Renewal	1.98	0.132	0.078
- Catch Basin Renewal	2.6	0.15	0.068
- Storm Sewer Upgrading (3)	27.77	1.85	1.023
- Traffic Signals Renewal	0.8	0.10	0.10
- Bridge Rehabilitation	7.59	0.76	0.450
- Lane Paving (3)	22.8	0.55	0.10
TOTALS:	138.94	13.832	11.931

(1) Approximate need to complete the projects in a reasonable time frame. The time frame for each project varies.

(2) 1989 Capital Budget need only - this figure is to escalate each year on top of inflation.

(3) Upgrading to present day standards.

FIGURE 2

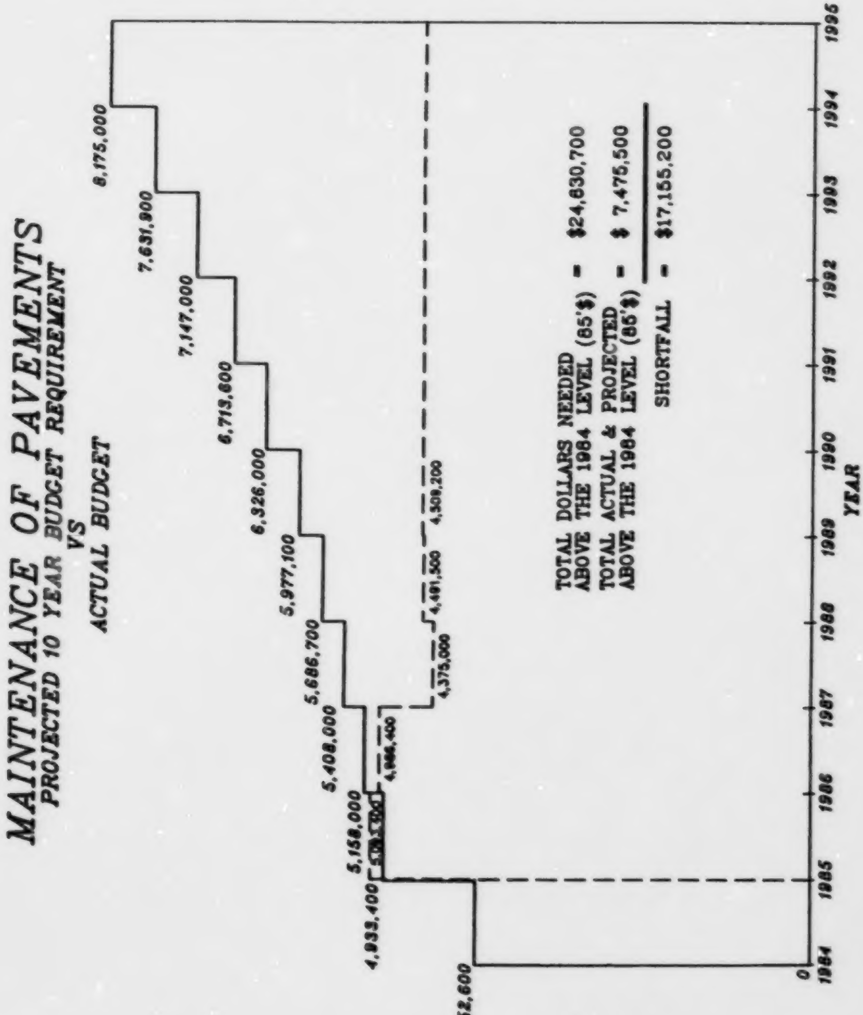
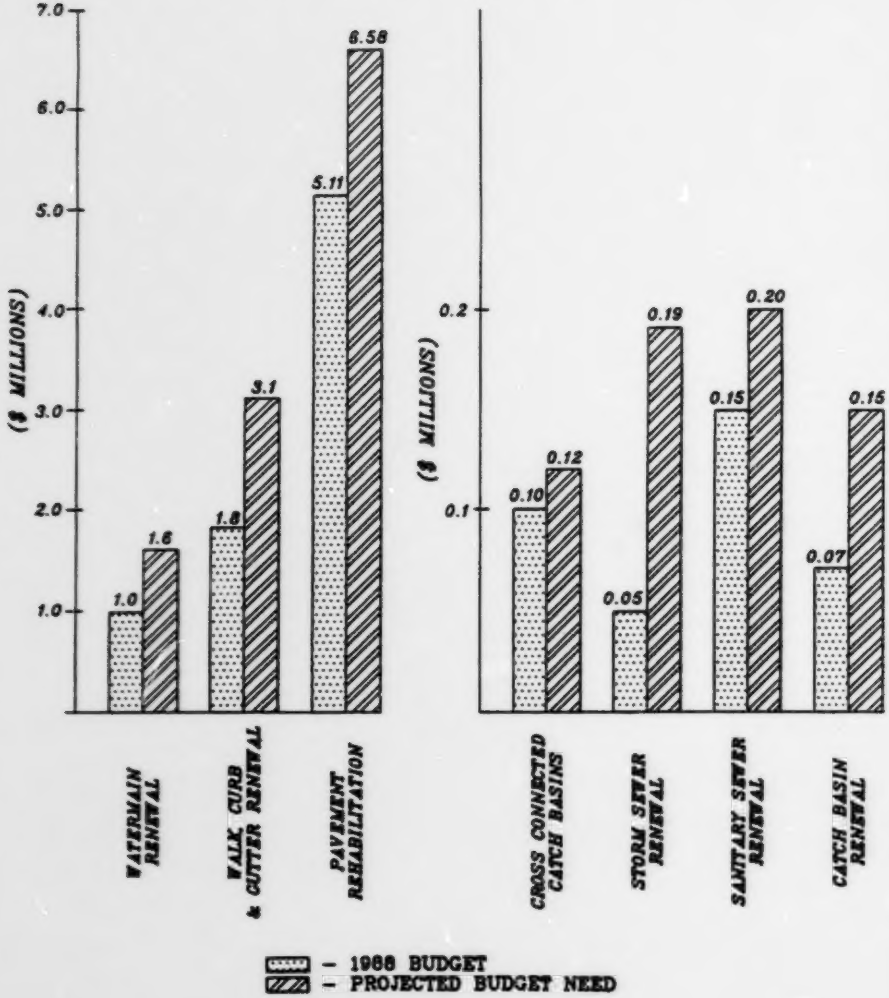

MAINTENANCE OF PAVEMENTS
PROJECTED 10 YEAR BUDGET REQUIREMENT
VS
ACTUAL BUDGET
DOLLARS
YEAR
0
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
3,852,600
4,933,400
5,158,000
5,408,000
5,686,700
5,977,100
6,326,000
6,713,800
7,147,000
7,631,900
8,175,000
4,986,400
4,375,000
4,491,500
4,508,200
TOTAL DOLLARS NEEDED ABOVE THE 1984 LEVEL (85'$) = $24,630,700
TOTAL ACTUAL & PROJECTED ABOVE THE 1984 LEVEL (85'$) = $ 7,475,500
SHORTFALL = $17,155,200

FIGURE 3

1988 BUDGET VS PROJECTED BUDGET NEED



In Regina, we feel we have made significant progress toward the objective to bring all infrastructure up to an acceptable condition and standard. But we know that we continue to fall short in the provision of funding. Clearly, a new financial strategy is needed to match the new awareness of this problem and the desire to solve it.

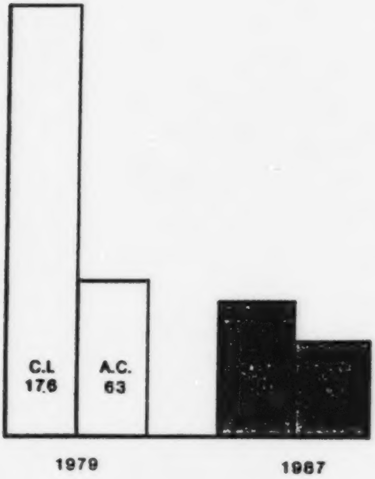


FIGURE 4: Watermain Breaks, Numbers and Materials, Regina.

GROUND-PENETRATING RADAR--SEEING IS BELIEVING

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ABSTRACT

Ground-Penetrating Radar (GPR), first developed in the 1940s, is a non-destructive geophysical technique that provides results broadly similar to those provided by an echo sounder. High-frequency, electrical energy is pulsed into the ground and the reflections can indicate inconsistencies in the underlying materials. Data collected from the GPR are presented as a grey-scale graphic record, and also on tape for post-processing.

The GPR unit is compact and portable and it is practical for use in many situations. With surveying speeds of up to 6 km/h, it provides a low-cost technique that can reduce the number of boreholes required.

The GPR technique can be used in both preliminary and detailed design engineering, and also in construction and maintenance. It can investigate road structures, utilities, soil and rock conditions, and ground ice.

Case histories are provided for its use in urban infrastructure redevelopment and in road, railway, and runway rehabilitation. Also, projects are described where GPR has been used for utility detection, pavement management, and the investigation of backfill behind tunnel linings, concrete delamination, road deterioration, and the rehabilitation of gas stations.

Although the GPR technique is not a panacea, it has many advantages over conventional techniques and is the only method capable of immediately providing such a broad spectrum of information to the engineer. The technique is recommended for use in urban engineering work, provided that care is taken to select an experienced contractor in this field and that all pertinent information is made available prior to commencing the survey.

RÉSUMÉ

Le géoradar se veut une technique géophysique non destructrice, d'abord mise au point dans les années 1940, qui donne sensiblement les mêmes résultats que la sondeuse ultrasonique. Des impulsions électriques à hautes fréquences sont émises dans le sol et les échos réfléchis permettent de déceler les anomalies des matériaux sous-jacents. Les données recueillies par le géoradar sont produites sous forme de registre graphique à échelle de gris et aussi sur ruban pour traitement ultérieur.

Le géoradar, compact et transportable, s'avère d'un usage pratique dans de nombreuses situations. Pouvant réaliser des levés à une vitesse pouvant atteindre 6 km/h, ce radar constitue une technique peu coûteuse permettant de réduire le nombre requis de forages.

La technique peut s'employer en génie aussi bien au stade préliminaire qu'au stade de la conception détaillée, de même qu'en construction et en maintenance. Elle offre la possibilité de sonder la structure des routes, les services d'utilité publique, l'état du sol et du roc, ainsi que la glace souterraine.

Des études de cas accompagnent son usage dans le cadre du réaménagement d'infrastructures urbaines et de la réfection des routes, des voies ferrées et des pistes d'atterrissage ou d'envol. On fait également état de travaux pour lesquels cette technique de radar a servi : détection des conduites d'utilité publique, gestion des revêtements en dur et sondage du remblai derrière le revêtement intérieur des tunnels, effritement du béton, détérioration des chaussées et réfection des postes d'essence.

N'offrant pas de panacée, le géoradar procure de nombreux avantages par rapport aux techniques conventionnelles et constitue le seul moyen capable de livrer sur-le-champ un vaste éventail de renseignements à l'ingénieur. Son utilisation est recommandée en génie urbain, à l'ingénieur. Son utilisation est recommandée en génie urbain, à condition de s'en remettre à un entrepreneur expérimenté dans ce domaine et de disposer de toutes les informations pertinentes avant d'entreprendre le levé.

INTRODUCTION

The success of indirect geophysical methods for engineering purposes depends heavily on experience. Because of its very nature, an indirect method needs control ("ground truthing") so that the collected data can be related to real objects. For many engineers, therefore, seeing is the only way of believing.

Engineers tend to prefer a tried and tested approach. We have seen many techniques come and go that promised to solve all of our problems and save us money. We have generally found, to our cost, that these techniques are fine in the laboratory but do not work either in all field situations or at all times (particularly in the rain); or, worst of all, do not tell us anything that we could not have found out cheaper and quicker the way we have always done it. Because of this experience, we are wary of new techniques.

Ground-Penetrating Radar (GPR) will not meet all of our subsurface information data requirements. It will not work at all in certain ground conditions. You would not even find many case histories to assure you of its applicability. What it will do, however, is provide you with fast, accurate data concerning many subsurface features of interest to the engineer working in an urban environment.

This paper presents the use of GPR in urban engineering. The paper describes the technique and its application, and presents case histories of its use.

TECHNICAL OVERVIEW

GPR is a non-destructive geophysical technique that is capable of delineating materials that have contrasting electrical properties. It is an established geophysical technique for such applications as the detection of subsurface anomalies and voids, profiling pavement structure components and the mapping of natural phenomena, e.g., ice wedges in permafrost soils.

The concept of GPR was first put forward in the 1940s when it was discovered that the radar altimeters in planes flying over the Greenland ice cap were measuring the depth to bedrock rather than to the height over the ice surface. The ability of radar to penetrate ice was explored over the 1950s and 1960s by several governments and used in mapping ice caps in several remote areas where large aerial surveys were required, the Antarctica in particular. In the 1970s, GPR broadened its area of application with its use by NASA on several lunar missions to measure certain characteristics of the surface of the moon. The involvement of GPR in the lunar program was one of the many technical advances that were introduced into the commercial market in the late 1970s, and early 1980s. In the early 1980s, the first commercially available GPR system was produced by Geophysical Survey Systems Inc. Initially developed to detect utility trenches in Boston, it was soon used in a variety of other situations. Examples of its current applications include locating rebar in nuclear power stations to determine optimum anchoring points for internal piping; profiling ice thicknesses for safety and maintenance programs on ice roads, and delineating the aerial and vertical extent of bauxite deposits.

Conceptually, GPR is very similar to an echo sounder. A pulsed, broadband, electromagnetic signal is transmitted into the ground. When the signal encounters a change in the electrical properties of the ground (specifically the dielectric capacity), some of it is reflected to the surface while the remainder continues to propagate into the soil until it encounters the next reflection interface. This process repeats itself until the strength of the reflected signal levels drops below the ability of the receiver to detect it. This depth is referred to as the depth of penetration and depends on the electrical resistance of the soil as well as the radiating power of the antenna being used.

The received signal is sampled by the receiving electronics. In the process of being downshifted to the audio-frequency range, it is horizontally stacked to improve the signal characteristics. The result is used to produce a grey-scale graphic record representative of the stratification below the antenna.

Operationally, the system comprises five essential components; a square-wave trigger generator, a high-frequency pulse generator, a transmit/receive antenna, decoder circuits, and a graphic plotter.

The square-wave generator triggers the high-frequency pulse generator causing a single high-frequency pulse (100 to 1000 MHz) to be transmitted at the beginning of the individual square wave. Each pulse is fed into the transmitting antenna which directs the pulse into the ground. The reflected signal received by the antenna is processed by the decoder circuits and sent to the chart recorder and magnetic tape. The hard-copy paper roll traces from the chart recorder are marked off in distance along one axis from which the location can be determined on the street. The magnetic tape provides a permanent record of the data and allows further digital processing, if required.

Depth of penetration and resolution of the signal are controlled by material properties and signal frequency. Higher frequencies provide better resolution but less penetration; lower frequencies penetrate further, but at the cost of lower resolution.

Operationally, this will effect the choice of antennas used in a survey. For example, pavement management surveys utilize a 1-GHz antenna because the application requires resolutions in the order of 2 mm, but penetration depths typically of no more than 1 m.

The other end of the spectrum is represented by site investigations where the horizontal extent of features below the road structure are of interest, i.e., ice-rich soils, etc. For these investigations the 120-MHz antenna is used giving resolutions of 0.3 m and penetration depths of typically 5 to 15 m, depending on the soil conditions.

APPLICATIONS IN CIVIL ENGINEERING.

Synopsis of Advantages

The radar unit is extremely compact and portable, requiring only a small electrical generator. It can be towed, placed on a small sleigh, or propelled in front of a vehicle (tracked or wheeled type), and is extremely adaptable to the local circumstances. It can be used in extremely cold northern environments as well as hot asphalt pavements under the southern sun. It requires minimal set-up time. For example, in the winter months, GPR can be used to assess the physical status of streets, so that come spring, potential costs of street repair will already be known prior to submission and approval of annual programs. As a business management tool, GPR can therefore be used to great effect.

Another significant advantage is the speed with which GPR can cover an entire area such as a subdivision. Typical vehicle speeds of up to 6 km/h and continuous operation minimizes traffic interruption. At intersections, every lane can be surveyed, including turning lanes.

With the high level of efficiency of operation in various conditions, the cost of implementing GPR is very low. In particular, it can be used to optimize more expensive borehole drilling programs, often significantly reducing the number of holes required.

Practical applications include:

- determination of road structure anomalies;
- pavement thickness by layer;
- variation in material types for road subgrades;
- rock horizons at shallow depths (< 5 m);
- ground ice inclusions in road/runway fills;
- utility construction and backfill assessment;
- reinforcement in concrete slabs for roads, runways, aprons, and parking structures;
- air void analysis in tunnel structures; and
- review of insulation components for northern roads and runways.

Preliminary Engineering

When used in the planning stages prior to detailed design work, GPR enables the design engineer to grasp the magnitude and complexity of the problems ahead. It provides an early warning system for potential problems, which can be investigated further before extensive work is undertaken.

GPR is an ideal tool for the location and preliminary identification of anomalies below road or ground surface. The continuous trace obviates the "hit and miss" type of placement of boreholes for preliminary soil and pavement investigations. Thus, the design engineer can feel much more confident in the planning of the borehole program. This program can concentrate on some of the anomalies discovered in the radar scan as well as more accurately plan the test program to provide more pertinent information.

When GPR is used as an aid to infrastructure engineering, for example, preparing to design for the rehabilitation of streets, arterials and highways, confidence levels increase immeasurably, because one can almost "see what is below the surface".

Detailed Design Engineering

One of the popular phases currently used in conjunction with infrastructure engineering is "pavement management systems".

These systems involve the assessment of the entire street, including determination of structural condition of the roadway. One of the problems with existing systems is that the location of subsurface anomalies which have a major impact on the condition of the roadway, cannot be determined. It is preferable, therefore, to be aware of any potential subsurface problems delineated by the GPR. These problems can be confirmed with either static or dynamic load-testing as part of the rehabilitation design. Without this level of awareness, load-testing becomes statistical, and essential and costly problems can be missed.

Similarly, the GPR can be used to determine inconsistencies in existing fill materials, including any voids that could create long-term problems. For pavement rehabilitation programs, the determination of such inconsistencies becomes important to the complete and thorough design.

Another area where "seeing is believing" involves the tracing of old utility construction. Often the inherent lack of adequate compaction will affect the integrity of road pavements and profiles. With the GPR unit it becomes very apparent where road maintenance crews have removed and replaced pavements structures over too small a patch area. The final area of settlement and more suitable size of excavation and patching can be predetermined from the radar traces. Cutting the correct size out of the road, and providing a more adequate size of patch enables the job to be done once rather than returning many times to that troublesome spot. In the detailed design phase of a project, the correct number and size of patches can be determined, and produce a better estimate of costs. Also, more suitable specifications and plans can be prepared prior to tendering.

Determination of rock horizons using GPR has promoted cost-effective decisions with regard to structural foundations for buildings. Its use optimizes the number of boreholes drilled and provides information about the rock formation and structural integrity. This has proven to be extremely useful in northern environments where the cost of drilling additional boreholes or making potentially costly assumptions on foundation types is always prevalent.

For northern/arctic design and construction, the ability to locate and delineate both the shape and form of ground ice is a significant advantage. In particular, it is very apparent that no matter how frequent the borehole pattern, the extent of ice lenses can only be determined by continuous trace methods. Because the GPR unit can accurately define the presence and shape of an ice lens, it is possible to design fills, overlays, and insulated pavement structures with confidence. Previously, if an ice lens was missed by the drilling program, the potential for both structural problems and expensive repair solutions was ever present.

We, therefore, have now the means to determine what is hidden below the surface and can prepare our designs accordingly.

Construction Activities

During construction, the GPR unit is a tool that can be used to check the depth and the consistency of pavement lifts in both asphalt and concrete. It has been suggested that, if indicator slugs are placed with the underlying pavement lift, a quick and accurate check of lift thicknesses can be made after overlay paving. These metal slugs would enable an accurate correlation of lift thicknesses throughout an entire project. The GPR unit could then be used for progress payment verification or for final acceptance inspections.

This year, the GPR will be used to determine the condition of the final product for an insulated runway in the Northwest Territories. In particular it will be used to ensure that none of the high-density insulation boards underlying the pavement structure moved during construction by verifying uniformity of the layer in place. Any problems with the insulation could require an expensive repair.

Maintenance

One of the most significant advantages of using GPR is its ability to penetrate the upper layers of pavement. That is, it permits a continuous examination of the condition of the base course, subbase, and subgrade by non-destructive means. Also, with it one can determine, at a very early stage, the pattern of cracking that is developing below the pavement, particularly where cement-stabilized gravel or soil/cement roadbases are used.

Typically, both urban and rural communities are attempting to create historical as-built information about their street and utility infrastructure for the development of pavement management and assessment rating systems. The GPR unit provides a fast and economical method for providing a substantial part of the historical information regarding a particular street or utility.

In areas where particularly heavy axle loads prevail, for example, on arterial roads, truck and bus routes, and specialty areas outside fire halls, the GPR provides a non-destructive method of determining the condition of the pavement structure. It can also provide a running record with annual "checkups" to enable the engineer to plan and budget for upcoming preventive maintenance repairs adequately.

EXAMPLES Or USE

Urban Infrastructure Redevelopment

As part of an overall infrastructure improvement program, a GPR survey was conducted by EBA Engineering Consultants for Associated Engineering Alberta Ltd. on the AMPLE project in the Inglewood subdivision in Edmonton. Every street and avenue in each direction was scanned with radar for a total of 16 working hours.

The entire study of 70 city block lengths and 60 block ends was completed at a cost of $7,500, including analysis and report. Information regarding the location of anomalies was available within 24 hours of scanning the entire subdivision.

Included as part of this program was an examination of the Groat Road arterial between 111 Avenue and 118 Avenue. As Groat Road is an extremely busy city arterial roadway, the ability to keep moving caused minimal traffic disruption. Also, because GPR is non-destructive, rehabilitation of potholes, created by continuous borehole drilling through good pavement, was refined.

Roads

GPR is ideally suited for the survey of long, linear features, such as roads. These features make the best use of its survey speed and its ability to accurately determine the thickness of such homogeneous materials as asphalt, soil cement, selected gravels, and the like.

The positive aspects of GPR have been consistently demonstrated on road projects throughout western and northern Canada. It has been used to:

- delineate layer thicknesses;

- detect local anomalies;
- identify base course types;
- detect and identify features not yet visible at the surface;
- delineate zones of ground ice, permafrost bulb and frozen ground;
- determine zones of potential instability;
- interpolate features between coring locations; and
- determine overlay thicknesses.

In all of the above, costs have been kept to less than $35/km, allowing for surveys both parallel and perpendicular to the road direction.

Railways

As with roads, the materials underlying railway lines have been easily surveyed using GPR techniques. Of particular interest is the use of the GPR in the survey of the Hudson Bay Railway for CN in northern Manitoba, where melting of the discontinuous permafrost presents on-going maintenance problems due to the subsidence of the track beyond acceptable tolerances. It is important, therefore, to delineate these zones of frozen ground so that maintenance can be planned and remedial measures evaluated.

More than 100 km of track has been surveyed for CN over 4 years, in order to rapidly delineate zones of potential settlement, optimize the exploratory drilling program, and provide input into the determination of the effectiveness of remedial measures.

Runways

Runways present survey requirements similar to those of roads, except that traffic delays are more critical. As with road works, the end-user is interested in the detection of anomalies both within and below the pavement structure.

GPR has been used to determine the underlying and performance characteristics of both asphalt and concrete pavements of several of the major airport runways, taxiways and aprons in southern Canada.

A survey was completed of runway 11-29 at Edmonton International Airport to detect anomalies and determine an optimum milling depth prior to overlaying the runway. The survey was successful in detecting movement of the concrete slabs, particularly in the touch-down zone, which was causing the long-term deterioration of the runway pavement. It confirmed suspicions about the mechanism (a high ground water table) responsible for such movements. It also delineated cracking features which had not appeared at the surface at the time of the survey. A complete survey of the 3000-m runway in three passes and several cross-sections was completed in 4 hours. Total costs for the project did not exceed $1,000.

Other Uses

There are several other types of project which have been completed using GPR and which are relevant to the engineer working in the urban environment. The following represents examples of the use of GPR by EBA in this environment:

Project Type: Utility Detection

Project: City of Yellowknife

Problem:

Precise location of utilities at present is not known. New construction requires detection and delineation of these old services.

Results:

GPR accurately identified duct banks, telephone cables, water, sanitary and sewer lines. Depths to pipes were measured providing a means of:

1. generating a profile along the top of the pipes to assess settlement rates and locations.

2 locating the pipes so that subsequent excavation could avoid interference with existing utilities, thus minimizing breaks in service; and

3. detecting anomalous zones within utility corridors, which may represent zones of saturated/frozen material which are related to settlement mechanisms.

Project Type: Utility Trenches

Project: City of Edmonton Water Line Replacement Program

Problem:

Breakage of old water lines and poor backfill compaction practices have led to subsidence of pavement structure over water lines. Because of repeated asphalt patching, the pavement structure has often partially bridged zones of subsidence. These bridged zones were missed in subsequent rehabilitation works.

Results:

GPR successfully delineated zones requiring rehabilitation beyond those marked by surface depressions. Also, the radar delineated several specific locations where voids were present under pavement structures where no surface expression was detected. It also identified zones of high organic soil content in the underlying subgrade fill material.

Project Type: Pavement Management

Project: Alberta Transportation Research Program

Problem:

Comparison of highway inventory record with actual construction. Derivation of mechanism for severe cracking seen at surface.

Results:

Transverse and longitudinal profiles were conducted over a 100-m stretch of representative road. Findings were as follows:

1. Full-depth construction was actually full depth with mixed base cover material over the eastern 20 percent of road width.
2. Asphalt was 67 to 93 percent of inventory values.

3. West side of road had thicker asphalt because of repeated patching, indicative of an unstable grade.

Project Type: Concrete Delamination

Project: Parkade

Problem:

Deterioration of concrete structure caused by delamination of concrete reinforcement due to salt ingress. The severity of the problem varied across parkade structure, at different stages of degeneration. Not all delamination was shown at the surface. Busy parkade could not be subjected to prolonged shut-down.

Results:

GPR accurately delineated zones of delamination not visible at the surface. Subsequent removal of concrete confirmed these findings.

It has performed well in locating the steel reinforcement in concrete slabs on a project where inadequate and improper spacing was giving rise to structural problems. In this context it can also be used to pinpoint areas for coring and further analysis.

Project Type: Road Deterioration in Northern Climate

Project: Manitoba Highways, Heat Pipe Test Site

Problem:

Detect freeze/thaw interface in settlement zones which are causing deterioration of the road grade.

Results:

GPR survey was completed over all four sites (which were up to 8 km in length) in 2 days. A total of 12 hole locations were flagged. The massive freeze/thaw interface was successfully isolated at three of the four sites. Separation distance between frozen and unfrozen holes in some cases was shown to be as little as 5 m. The entire program, including drilling, site selection, and instrumentation installation, was completed in 5 days. Distance from northernmost to southernmost site is 70 km.

In the Northwest Territories it has been used to locate and define ice lenses in road fills on the Dempster Highway, and will be used this year for both rock horizon definition and performance of insulating materials for the new extended runway at the Rankin Inlet NORAD base being designed by Associated Engineering Alberta Ltd.

Project Type: Tunnel

Project: City of Edmonton Highlands Trunk Sewer

Problem:

Loss of ground behind tunnel; segmented liner caused voids which were unacceptable to tunnel load design. A grouting program was initiated, but there were fears that voids could be missed.

Result:

GPR was used to scan behind tunnel walls in several suspect sections of the tunnel. GPR showed cracks both close to the liner and at some distance from the liner. Water-bearing gravel zones were also detected close to the liner.

Also some evidence of previous grouting was discovered. No major voids were detected. Most features appear to be associated with the positioning of the tunnel liner such as cracks at the liner joints).

Project Type: Gas Station Rehabilitation

Project: Urban Gas Station Rehabilitations

Problem:

Gas station sites to be used for future construction often have various levels of soil contamination, old services, and tankage that must be removed prior to development.

Results:

> GPR accurately identified pipes, utility trenches, and buried tanks. Also, in several cases, GPR accurately identified the presence of gasoline, fuel oils, and solvents in the soil. The extent of the plume was delineated on a grid pattern, and zones for excavation were marked. The presence of water-saturated soils immediately under the concrete slabs was detected providing ideal conditions for the detection of free hydrocarbon on the water table.

CONCLUSION

Although far from being a universal panacea, GPR has many advantages over conventional techniques in that it is the only method available commercially that can provide such a broad spectrum of immediate information to an engineer. We believe that this technique is of merit and recommend its careful adoption by engineers practicing in this field. We recommend that care be used in the selection of an experienced contractor to carry out the work and that the engineer ensure that the contractor is fully aware of the ground conditions in the target area. In this way, the chances of the survey providing adequate results can be predicted ahead of commencing work. We also recommend that "ground truthing" be carried out in all cases, if only to confirm the data collected or to investigate anomalies.

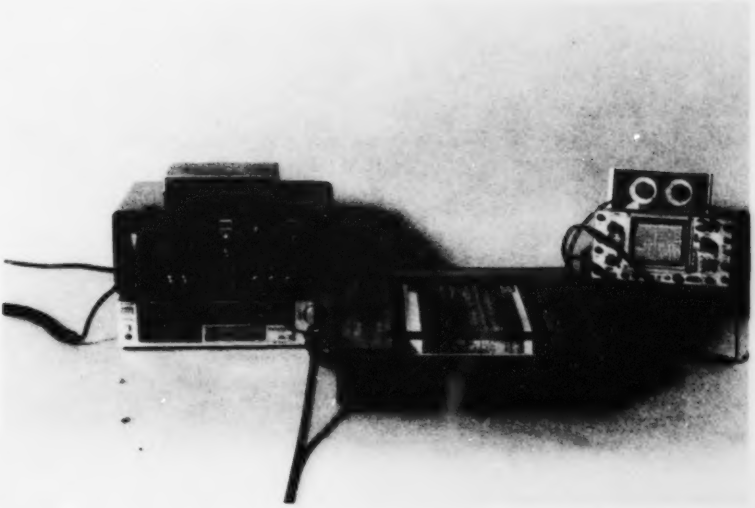

PLATE 1. Ground Penetrating Radar System Componants

PLATE 2. GPR 120 MHz Survey, Skid Configuration

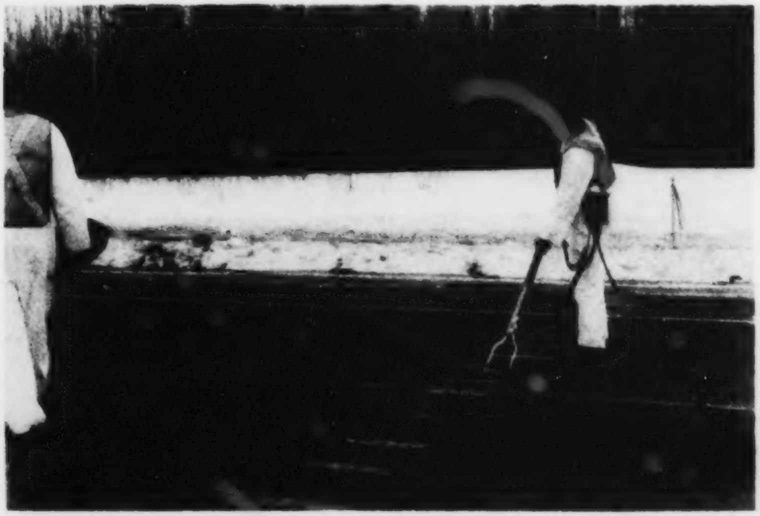

PLATE 3. GPR 1 GHz Survey, Tranverse Profiling

DEVELOPMENT OF REALISTIC INFILTRATION/INFLOW HYDROGRAPHS FOR SANITARY SEWER SYSTEMS ANALYSIS AND DESIGN

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ABSTRACT

Prior to 1980, infiltration/inflow was considered a minor contributor to sanitary flow during wet weather conditions. The City of Edmonton's 1982 Master Drainage Plan recommended that a 20 percent extra over design dry weather flow be used in the planning of sanitary sewer systems.

Since then, extensive basement floodings in the separated sewer areas such as Millwoods during wet weather conditions have triggered sewer evaluation survey works at the problem areas. Findings of these surveys showed that in most areas back-up flows from sanitary sewers had been the main cause of basement flooding. These excessive sanitary sewer flows originate from various sources of infiltration/inflow (I/I).

Field observations and monitoring over the years at various drainage basins have proved that I/I has a major impact on the City's sewer collection systems under wet weather conditions. The current Master Drainage Plan conducted by the City of

Edmonton initiates an attempt to identify the various components suspected of contributing to the total I/I to the systems.

The major components considered in the study comprises manhole inflow, weeping tile I/I, and infiltration via sewer cracks.

This paper describes the rationale behind the development of a set of I/I hydrographs for the flow simulation process using an updated version of SWMM model. Also, this paper describes practical application of I/I hydrographs.

RÉSUMÉ

Avant 1980, on ne croyait pas que les afflux et les infiltrations avaient beaucoup d'influence sur le débit des égouts séparatifs par temps pluvieux. Le Grand Plan de drainage établi pour la ville d'Edmonton en 1982 recommandait néanmoins d'utiliser pour la planification des réseaux d'égouts séparatifs un débit de 20 p. 100 supérieur à leur débit théorique par temps sec.

Depuis lors, divers cas d'inondation majeure de sous-sols, par temps pluvieux, dans des zones équipées d'égouts séparatifs censément séparés - Millwoods, p. ex. - ont incité les autorités à réévaluer les réseaux d'égouts de ces zones. On a alors constaté que le refoulement des égouts séparatifs était, dans la plupart des cas, la principale cause de l'inondation des sous-sols. Le débit excessif des égouts séparatifs résulte de diverses sources d'afflux et d'infiltrations.

L'observation et le contrôle de divers bassins de drainage, au fil des années, a démontré que les afflux et les infiltrations ont une incidence considérable sur le débit des réseaux d'égouts séparatifs de la ville par temps pluvieux. Le Grand Plan de drainage auquel se réfère aujourd'hui Edmonton essaie de cerner les diverses causes soupçonnées du débit total des afflux et infiltrations dans les réseaux d'égouts.

Les principales sources examinées au cours de l'étude étaient les afflux dans les regards, les afflux et infiltrations dans les tuyaux de drainage et les infiltrations dues aux fissures de la paroi des canalisations d'égout.

L'exposé décrit les motifs de l'établissement d'un jeu d'hydogrammes des afflux et infiltrations pour la simulation du débit des égouts à l'aide d'une version à jour du modèle SWMM. On verra aussi comment utiliser ces hydrogrammes dans la pratique.

URBAN INFRASTRUCTURE NEEDS OF MANITOBA:
RELATIONSHIPS BETWEEN
INFRASTRUCTURE, ECONOMY, AND ENVIRONMENT

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ABSTRACT

An overview of the situation in Manitoba highlighting the major achievements to date while pointing out the deficiencies and needs for further development. Cases where the absence of infrastructure is retarding economic development will also be considered.

RÉSUMÉ

Un survol de la situation au Manitoba met en lumière les grandes réalisations jusqu'à ce jour tout en pointant les déficiences et la nécessité de pousser le développement. On envisage les cas où l'absence d'infrastructure retarde le développement économique.

The importance of the role of the infrastructure in ensuring a sound economy and a healthy environment has been underestimated. Infrastructural services are quite literally the foundation upon which our homes, businesses, and industries are built. For example, our farmers have a direct stake in rail lines and port development in order to get their produce to market. Our manufacturing sector requires proper roads, bridges, and rail lines to maintain access to raw materials and to transport their finished product to the market place. And, our communities require sufficient water and sewage facilities for disease control and proper sanitation.

If this infrastructure is allowed to deteriorate it will have a negative impact, not only on our prairie economy, but also our national economy because of the interdependent nature of our economies. The 1984 FCM study clearly illustrated the deteriorated nature of much of our infrastructure.

A recent study conducted by the Federal Reserve Bank in the United States has identified a close correlation between productivity and public spending on infrastructure for the years from 1950 to 1985. A bank spokesman stated the public resources invested in systems which aid in the production and distribution of goods and services have a direct impact on the profitability of industry which, in turn, spurs private sector investment.

So, without good infrastructural facilities we can expect the productive capabilities of our communities, and therefore our national economy, to decline, resulting in many lost jobs and a declining quality of life.

We cannot ignore the growing problem of infrastructural deterioration, because to do so means that our economy will suffer a reduction in its economic potential, productivity, and jobs; and we will suffer a loss in the quality of life and in the choices open to us in the future.

Money spent on infrastructure refurbishing is wealth-generating; that is, the dividends accruing from such funding far outweigh the initial investment. The cycle of benefits is obvious: construction creates jobs, material purchases, salaries, and tax revenue. Senior government benefits by increased income tax revenue and by no longer paying unemployment insurance. And, of course, there are spin-off benefits to the economy by way of increased consumer spending. All of these add up to greater economic prosperity.

The ties between infrastructure and economy will become even more closely bound as our businesses learn to compete in an increasingly global market place. To achieve and maintain a competitive edge, quality up-to-date infrastructure will be very important.

The state of the environment has become an issue of major concern to most Canadians. The state of our infrastructure, however, is such that it often impinges adversely on the environment; for example, the pumping of untreated sewage into our waterways.

The federal government has recently embarked on a new development approach which recognizes the relationship between economy and environment, called sustainable development. Manitoba is very supportive of this approach to development which does not degrade opportunities for future generations. I think public spending on infrastructure by local and senior governments will be absolutely essential to ensure not only increased productivity but also a healthy environment.

Let me give you some examples from Manitoba. We have a number of regional centres that have both thriving "dry" and "wet" industries. Many of these "wet" industries are expanding their scope of operations which means investment and jobs in the regions and increased export of value-added goods. Their water needs are sizeable, however, and their liquid effluents diverse and difficult to process.

In many Manitoba communities, the existing water systems are a constraint to economic growth and a severe limitation to any future expansion of some industries. Environmental hazards are also occurring because of inadequate systems.

Much of Manitoba's water and sewer infrastructure dates from the 1950s. There has been considerable deterioration of this existing infrastructure, to the extent where many communities are unable to meet minimum provincial environmental and other standards.

There are a number of reasons leading to the inadequacy of municipal infrastructure, including:

- rapid inflation a few years ago in municipal taxes;
- reduced federal contributions, priorities shifted focus to provide for a growing array of social programs;
- high interest rates;
- expansion of the food-processing industry;
- available funds directed to expansion instead of maintaining existing infrastructure;
- inadequate coordination between the planning of development and the planning of infrastructural facilities;
- growing environmental concerns and increasing public involvement in decision-making has made construction projects more difficult to initiate and more expensive to undertake;
- the inability of some municipalities to provide for adequate infrastructural facilities through long-range financial planning; and above all
- budget cut-backs affecting maintenance and repair programs, because of their low public visibility and unglamourous nature.

What are the projected capital expenditures for municipal infrastructure in Manitoba? For the period from 1988 to 1993 for water and sewer, they amount to $229 million or 20 percent of total projected expenditures.

Projected capital expenditures for transportation infrastructure are even greater. These figures read $541 million. The costs of transportation infrastructure maintenance and replacement have gone up dramatically. It is clear in Manitoba, as in other prairie provinces, that a major restructuring of our transportation infrastructure is underway with rail line abandonment. This restructuring has negative impacts on the road system and on individuals and municipalities. For example, there are increased road costs incurred by the province and its municipalities by the diversion of traffic, there are additional trucking costs that accrue to grain producers in accessing more distant elevators, and there is the loss of elevator and rail taxes by municipalities.

An alternate transportation infrastructure will be required to replace conventional branch line service. This void could readily be filled by diverting some of the savings realized by rail abandonments to the alternative systems.

Even without rail abandonment, there has been an ever-increasing shift in the share of traffic from rail to truck. However, the lack of a national highways policy is a major impediment to the unencumbered flow of interprovincial commerce. Hopefully, the recently appointed technical steering committee, chaired by Boris Hryhorczuk, Deputy Minister of Manitoba's Department of Highways and Transportation, will be able, by late 1990, to recommend a policy which Canada's transportation ministers can agree to.

I have referred to our infrastructural needs in Manitoba in the two most important areas, which are transportation, and water and sewer. I would now like to take a few minutes to examine the fiscal capacity of our local government.

In Manitoba, as previously noted, many communities installed their water and sewer services in the 1950s, and these systems, for which debentures have just been fully paid off, require replacement or renewal. In fact, some have required extensive upgrading even before the debt issued to finance them had been retired, increasing constructions costs, and higher engineering standards have contributed toward replacement costs far exceeding the initial cost of these systems. In some of the smaller urban centres, replacement costs are actually beyond the financial capacity of the communities. The reason for this is that there is very little commercial/industrial assessment to contribute toward the payment of debt in most of these communities, so the entire load falls upon the shoulders of the residential property owner.

I believe there lies a challenge here for our municipal engineers to bend their minds to innovation and imagination, to develop and utilize new technologies which will add to the durability and life-span of our infrastructure facilities. As has been stated by Mike Ircha of the University of New Brunswick:

> "Today's growing infrastructure rehabilitation needs demand a shift away from development and construction towards an emphasis on maintenance and rehabilitation."

Given shrinking budgets and increasing costs, I think it is absolutely essential that products and methods be developed which are more cost-effective. We can be sure that the costs of rehabilitation facing us now will be dwarfed by the staggering costs in the future to replace and rebuild our infrastructure.

In Manitoba, we have a guideline that long-term debt obligations of a municipality shall not exceed 30 percent of its assessed value. In most small urban centres with limited tax base, this means that one major project can push a municipality beyond acceptable borrowing limits.

An answer to this, albeit a long-term one, is to have municipalities increase consumer charges to provide funds which can be set aside in separate reserves for the replacement of ageing systems. This raises a question of generational equity - should today's users, at the same time as they may be paying off debt on their water and sewer system, be setting aside funds to replace that system for the benefit of tomorrow's users?

The question of ageing systems obviously deserves attention - the question of ageing populations must be considered, too. In some of Manitoba's smaller urban centres, as much as two-thirds of the population is over the age of 60. This leads one to wonder

A. If the existing system is upgraded to extend its life by 35 or 40 years, will there be anyone left to use it?

B. If the municipality assumes debts to pay for the cost of replacing the system, will there be anyone left in 20 years to continue to make payments on the debts?

One of the problems with smaller communities attempting to attract industry in order to, among other things, broaden their tax base, is that such industry may place a lot of stress on existing water and sewer systems - even to the point where the systems may have to be expanded simply to accommodate the additional demands of the industries. To expect the local communities to pay the entire cost of expansion is unrealistic, because the economic benefits of the industries are provincial and national in nature.

It is ironic that there may even be federal government programs, such as the western diversification initiative, which will encourage such industries to set up in rural communities while at the same time refusing to provide assistance so that the communities may expand their infrastructure in order to accommodate the industries.

A greater public awareness of environmental and public health concerns has resulted in the raising of standards for wastewater treatment. Therefore the costs of sewage collection and disposal facilities are comparatively higher now than they were 25 or 30 years ago. In Manitoba there are approximately two dozen smaller urban centres that are under order of the Clean Environment Commission to improve sewage treatment facilities.

I would like to give you one example from Manitoba to illustrate the fiscal bind in which a local government may find itself.

The City of Portage La Prairie has a population of about 13,000 and is located about 80 km west of Winnipeg. It is a regional centre for the fertile "Portage Plains". In addition to service activities related to agricultural production, the city has a large industrial park providing service for food processing and light manufacturing industries. The city is serviced with treated water drawn from the Assiniboine River and a wastewater collector and treatment system based on a deep-shaft process and polishing lagoons.

The existing wastewater treatment system is overloaded and the City has been ordered by the Clean Environment Commission to install additional facilities. Further residential and industrial expansion is paused pending the provision of the additional facilities. In addition, further expansion of the industrial park requires increased treated water transmission and storage capability. Feasibility studies to identify the most cost-effective method to achieve these objectives are currently underway.

Over the past 25 years, the city has developed as a leader for vegetable production and processing. A combination of soil quality, frost-free days, and access to irrigation from the Assiniboine River have led to vegetable and potato production processing.

Over the past 25 years, the city has developed as a leader for vegetable production and processing. A combination of soil quality, frost-free days, and access to irrigation from the Assiniboine River have led to vegetable and potato production processing.

A number of significant "wet" industries have established in the City of Portage La Prairie over the years, especially Campbell Soups and McCain Foods. These industries have contributed significantly to the economy not only of the city but also to the province and, indeed Canada.

An engineering feasibility study has indicated the total cost of upgrading to be $36 million. On a per-capita basis, this amounts to $2,800 - clearly a community the size of Portage La Prairie cannot on its own handle such costs.

If one attempts to keep the maximum debt load carried by the city to 30 percent of its assessment then clearly senior governments will have to make up the balance. There is justification for this if one considers that the economic benefits from the "wet" industries in Portage La Prairie accrue more to the province and Canada than to the city.

In my opinion, it is absolutely essential for the senior government to involve itself in the rehabilitation of our infrastructure, if this country's economy is to thrive and if our environment is to be safeguarded for future generations. Not to do so will cost us in terms of lost productivity, in terms of lost economic opportunities, and it will hurt us in terms of lost jobs.

OVERVIEW OF THE SITUATION IN SASKATCHEWAN

D. M. Innes
Deputy Minister
Municipal Affairs, Saskatchewan

ABSTRACT

An overview of the situation in Saskatchewan highlighting the major achievements to date while pointing out the deficiencies and needs for further development. Cases where the absence of infrastructure is retarding economic development will also be considered.

RÉSUMÉ

Quel est l'état des infrastructures urbaines en Saskatchewan? Qu'a-t-on fait pour remédier au problème et que faudrait-il encore faire? On examinera les principales réalisations à ce jour et les améliorations qui demeurent nécessaires. On verra aussi comment l'absence d'infrastructures urbaines retarde le développement économique de certaines localités.

SPEECH TO THE CANADIAN CONFERENCE ON URBAN INFRASTRUCTURE

EDMONTON CONVENTION
CENTRE

FEBRUARY 13, 1989

The Honourable Archie Grover
Alberta Deputy Minister
Municipal Affairs
Edmonton, Alberta

ABSTRACT

An overview of the situation in Alberta highlights the major achievements to date and points out the deficiencies and needs for further development. Cases where the absence of infrastructure is retarding economic development are also considered.

RÉSUMÉ

L'aperçu de la situation en Alberta fait ressortir les principales réalisations accomplies jusqu'ici, de même que les déficiences et la nécessité de pousser l'aménagement. L'exposé fait également ressortir les cas où l'absence d'infrastructure retarde le développement économique.

Just how vital a municipality's infrastructure is was amply illustrated 2 weeks ago here in Edmonton when we experienced the heaviest snowfall ever recorded for a January, followed by a 1-in-10-year cold snap. The road surfaces were like washboards, more suitable for a Red River cart than today's automobiles. This, of course, was not due to the road surfaces themselves but to the accumulation of snow and ice. However, it did serve as a reminder of the past and what could happen in the future, if we allow our infrastructure to deteriorate because of lack of attention due to a shortage of funding. The -30 to -40°C temperatures also had watermains breaking.

Some people will tell you that what happened 2 weeks ago is only a harbinger of things to come. Not because of the snow and the cold, but because of a crumbling infrastructure. Roads will be a quagmire of ruts and potholes; water and sewer troubles will be an everyday occurrence; there will be uncontrolled pollution and fear of disease. And while that may be a legitimate concern in some parts of this country, I don't believe, based on an observation of the facts as I have experienced them in this province, that will be the case here in Alberta.

That is not to suggest that we do not have infrastructure problems and concerns - we certainly do. But, for the most part, I believe they are manageable.

In 1987, we carried out a survey of municipal infrastructure in Alberta. We wanted to know not only the current situation and condition of existing infrastructures, but we wanted to build a firm foundation on which we could plan for the future.

The survey turned up some rather interesting facts. One of the most significant being that the majority of Alberta's sanitary and storm sewers and the treated water systems are less than 25 years old. For example, 74 percent of the cities' storm sewer systems are within that quarter-century age bracket. When we looked at villages, it was an even more startling percentage: 90 percent are less that 25 years old. A look at sanitary sewers showed that 60 percent of those in urban areas are less than 25 years old. Thirty-three percent are between 25 and 50 years old.

The majority of the treated water distribution systems were also installed in the last 25 years. Only 5 percent of these systems are over 50 years old.

Just to carry on a bit further with the survey findings: the majority of pipes in place in all urban centres, both sanitary and storm sewer systems, are concrete. Corrugated metal pipes and clay tile pipes are also commonly used. Pipes made from other types of metal make up the least number of metres per capita in the system. In the treated-water systems, the majority of the pipes are asbestos-cement. Ductile iron and other materials make up only 1.7 m per capita.

I know that many of you will be saying that Alberta is lucky and, in a sense, Alberta is fortunate to be a relatively young province, with a reasonably new urban infrastructure.

But, as I mentioned earlier, not everything is rosy. Our two major cities, Calgary and Edmonton - which account for half of the province's population - are faced with replacing an ageing core infrastructure. Some of those two cities' systems are 70 years old and their capacity does not meet current needs.

So what are we doing about it?

As it turns out, I think that we are doing quite a bit about it in Alberta. One of the most innovative initiatives that we have taken is the Alberta Municipal Partnership in Local Employment or, as it is perhaps better known, the AMPLE program. It is an unconditional grant system under which the provincial government expects to provide $500 million to municipalities over a 7- or 8-year period which began in 1987.

To explain AMPLE, one has to go back to the late 1970s and early 1980s - the Boom Years. Alberta's municipalities were extremely active in developing their communities, and they were borrowing in record amounts from the Alberta Municipal Financing Corporation to fund their local projects. During this period, interest rates escalated to extremely high levels, and the provincial government decided to assist municipalities in handling their debt load by providing grants under the Municipal Debenture Interest Rebate Program. Under this program the province subsidized loans to municipalities first at 9 percent, then later at 11 percent.

To meet the especially high demands of 1981 and 1982, the Alberta Municipal Financing Corporation borrowed money from the Alberta Heritage Savings Trust Fund and from the Canada Pension Plan at high interest rates. Much of the municipal borrowing during this period has being amortized over 20 to 25 years. The corporation decided not to match the 20- to 25-year borrowing terms of the municipalities, opting instead to borrow for 5 to 7 years. As a result, almost $1.2 billion in corporation debt was scheduled for refinancing between 1986 and 1989.

By 1986, the interest rates had dropped substantially and the benefits of this refinancing were passed on to municipalities through the refinancing of outstanding debentures. The department had in its budget $120 million dollars to subsidize interest rates; as a result of refinancing municipal debt, this amount was not needed. The government decided to retain the budget at $120 million dollars and to turn the excess over to all municipalities on a per-capita basis. Thus AMPLE was born. I should point out that AMPLE is an unconditional grant and, as such, is not specifically targeted at infrastructure replacement. However, the program is aimed, as the name implies, at generating employment in the various Alberta communities. Infrastructure replacement is, quite obviously, labour-intensive and our research indicates that most communities use the AMPLE funds, in whole or in part, to replace, improve, or expand municipal infrastructure.

To give you a perspective on how this works in real terms, let me give you a few more financial facts. In fiscal year 1988/89, AMPLE grants totalled $57.5 million, or $24.17 per capita. This year, they will increase to almost $67 million, or at least $28 per capita. The City of Edmonton alone, for example, received almost $20.8 million during the first 2 years of the program.

And our financial support of Alberta's municipalities does not stop there. The Department of Municipal Affairs administers another major grant program which, from a financial point of view, has an even greater impact than AMPLE: the Alberta Partnership Transfer (or APT) program. APT, which was announced in January 1988, combined individual payments that had been made for municipal assistance, law enforcement, and public-transit operating assistance into a single, unconditional grant to all municipalities.

In the first year, the APT grant totalled just over $147 million. This year, APT will increase to approximately $153 million. I appreciate that all of these funds cannot be earmarked solely for infrastructure since municipalities have many other issues that deserve their attention. However, these two grants alone, and I stress that these are only two programs administered by the Department of Municipal Affairs, make a considerable amount of money available to Alberta's municipalities. And, as I have already noted, these funds are unconditional - municipalities can use them in virtually any manner they wish.

The City of Edmonton again received almost $91.8 million during 1987 and 1988 as a result of Alberta municipal affairs programs. In 1987, the grants through interest stabilization, AMPLE, and the municipal assistance grant portion of APT gave Edmonton over $50 million. In 1988, those same programs contributed over $41 million. And these figures do not include the dollars available through APT associated with the law enforcement or public-transit operating assistance grants. Nor do they include grants associated with the other government departments. They relate only to the major programs handled by the Department of Municipal Affairs.

Needless to say, Alberta municipalities benefit from a full range of funding programs provided by many other government departments. The Alberta Municipal Water Supply and Sewage Treatment Assistance Programs administered by Transportation and Utilities provided approximately $40 million for infrastructure in fiscal year 1988/89 and plans to make a further $35 million available this year. In addition, that same department recently announced a new program called the Alberta Cities Transportation Partnership Program that will provide $500 million to municipalities over a 5-year period to address transportation concerns.

While money is always nice, I think municipalities have benefitted in many other ways through provincial involvement. For example, we have established regional utility services commissions to provide water and sewer services to several participating municipalities. Combining the resources of several municipalities into one system provides for more extensive and sophisticated systems than individual municipalities could often manage. To date, we have established nine such regional systems, and I am pleased to tell you that they are all very successful.

I am aware that there are many at the municipal level who feel that the only answer is a mass infusion of dollars from the federal, provincial, and municipal levels of government. They believe that this is the only answer to their current problems. Perhaps they are right. But I think I should point out a few things about that type of approach. If we assume the obvious, there will be a tremendous imbalance in the need for funds. The larger, older centres (primarily in eastern Canada) will need the greatest assistance. The smaller, newer western centres will need the least assistance. And that's a political dilemma I am glad I do not have to wrestle with.

In order that there will be an equitable distribution of funds from the federal level - if, in fact, there are any at all - we believe they should be distributed on a per-capita basis. This would not penalize those municipalities that have made a concentrated effort to keep their infrastructure in good repair, such as the City of Calgary has done.

And where will the federal funds come from? Higher taxes, which will assume that western communities (who, as I have already pointed out, will probably require the least assistance) will be asked to subsidize those needing the most help? At a time when the federal government has targeted the deficit as a major problem, is it likely that such federal funding will be new money? That seems improbable. Most likely it will result in a withdrawal of funds from existing programs. We in Alberta support the F.C.M. in urging the federal government to be a partner with the provinces in this most important initiative.

And how about the provincial funding component? Are most provinces in a position to assume a far greater debt? I think not. Rather, provincial contributions will come from increased taxes or a reassignment of existing funds.

I would also be curious to know from where the municipalities will get their contribution to the program. By taxing their ratepayers? That hardly seems likely. By assuming greater debt through borrowing? For many communities that would be tantamount to suicide.

I think that we have to be practical and work together within the existing constraints as we understand them. We have to prioritize our needs. We need to find ways to be economical. And we need to be creative in dealing with these problems.

In Alberta, I believe we have found a way to deal effectively with these issues. Our approach certainly requires patience. The problems will not be resolved overnight, unless we are prepared to mortgage our future beyond all reasonable bounds. And this we will not do. But we have established a good working relationship between the provincial and municipal levels of government. Progress is certainly being made on the question of infrastructure in this province. Our approach may not be the best for everyone, but I do believe that each province can develop a method for dealing with the problem - it is a matter of creative thinking.

There is no question that much still needs to be done. But, in Alberta, much has already been done. And we will continue to work together, the province and the individual municipalities, to ensure that Albertans have a standard of living that they have come to expect, and indeed have a right to demand.

THE CITY OF RED DEER'S BRIDGE MAINTENANCE PROGRAM

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ABSTRACT

Over the past 13 years, Reid Crowther and Partners Ltd., in conjunction with the City of Red Deer, Alberta, have been involved in the development and implementation of a comprehensive bridge maintenance program. The initiation of this program arose from the City's realization that environmental and traffic conditions have in some urban locations slowly deteriorated bridges to the point where public safety is at risk and that the return on the initial capital investment, in terms of a reduced effective life of the structure, is inadequate.

This paper will outline the objectives of the City of Red Deer's bridge maintenance program and describe its various components from inspection through to reporting and maintenance activities. Also included is a discussion of the economic aspects of a properly planned and managed bridge maintenance program.

RÉSUMÉ

Depuis 13 ans, la firme Reid Crowther and Partners Ltd. participe en collaboration avec la ville de Red Deer en Alberta, à l'élaboration et à la mise en oeuvre d'un programme global d'entretien des ponts. La mise en branle de ce programme tient au fait que la municipalité s'est rendu compte que l'environnement et la circulation ont lentement détérioré les ponts dans certains mileux urbains au point de compromettre la sécurité publique, et que le rendement de l'investissement de capital initial, équivalant à une réduction de la durée utile des structures, se révèle tout à fait insatisfaisant.

L'exposé met en relief les objectifs du programme d'entretien des ponts de la ville de Red Deer et fait état des diverses étapes s'échelonnant de l'inspection proprement dite jusqu'au compte rendu d'activités et aux travaux d'entretien. On y traite également des économies que permet de réaliser un programme d'entretien des ponts bien planifié et bien géré.

INTRODUCTION

It has been well documented that the deterioration of bridge structures in Canadian urban areas is a major concern in light of our severe environmental conditions coupled with high volumes of traffic. The need for mobility in urban areas demands that our roadway systems be kept in good repair. Bridges are an intricate part of that system. Remedial measures or load restrictions on bridges decreases the efficiency of the system, resulting in inconvenience to the general public.

In a study report released by the Roads and Transportation Association of Canada (RTAC) on the status of the nation's roadway system infrastructure it was noted that it would take over $587 million annually to preserve our roadway bridges. Over $262 million of this is required for urban bridges alone. The report also identified that current spending on bridges is substantially less than that required to keep them in good repair.

Most of the bridges are more than 10 years old. As a result, they most likely have not been designed or constructed to prevent the corroding of reinforcing steel in concrete adequately or carry the present highway loads without adversely affecting the performance of the structure as a whole. Government authorities responsible for bridge structures are now in the position of maintaining these structures which are being operated under conditions which were not originally anticipated at the design stage.

Recent catastrophic bridge failures have proven the need for proper inspection and maintenance of bridge structures. The general public and political decision-makers are slowly coming to the realization that their bridges will not last forever on their own accord. Government agencies are being forced to review their current practices and identify the need for a comprehensive bridge maintenance and management system. The City of Red Deer are considered leaders in the Province of Alberta with the timely initiation of its bridge maintenance program.

The primary objectives of the City of Red Deer's bridge maintenance program are:

- to ensure a reasonable level of safety to the general public.
- to protect the initial capital investment by extending the useful life of the structure to the optimum,
- to complete maintenance repairs cost-effectively, and
- to maintain a management system for the planning and funding of the maintenance and rehabilitation of the City's bridges.

It is important to note that it is not an objective of this program to maintain the City's bridges in a "brand new" condition because the cost implications are not consistent with the objectives.

This paper discusses the development and implementation of the City of Red Deer's bridge maintenance program. Included are discussions pertaining to the specific components of the program, the City's infrastructure as it pertains to bridge maintenance, and the economic aspects of the program.

THE CITY OF RED DEER, ALBERTA

The City of Red Deer (population: approximately 55,000) is located in central Alberta about halfway between Edmonton and Calgary, situated along the banks of the Red Deer River, a major river running from west to east through the center of the city. Other important water courses are the Waskasoo and Piper creeks which wind their way throughout the southern half of the city.

CP Rail track runs north/south through the city, and there is a railyard at the heart of the city. Plans are currently underway to move this track and the yard to a location outside the city proper in order to improve the City's transportation system and to develop the city centre.

The City's roadway system consists of approximately 300 km of paved road with 15 bridges and 4 large culverts. Each structure has been given an identification number for referencing purposes. (Table 1 is a list of the City's inventory of bridge and culvert structures.) Included in this table are the age of the structure, type of structure, number of spans, and an estimate of the capital investment in 1989 dollars.

DEVELOPMENT OF THE BRIDGE MAINTENANCE PROGRAM

Before initiation of the formalized bridge maintenance program, the maintenance and rehabilitation of bridge structures within the City of Red Deer was, like with many other Canadian cities, more reactive than proactive.

In 1976, Reid Crowther performed the first maintenance inspections of three structures requiring repair. In 1977, the engineering services manager requested that Reid Crowther complete an inventory and perform inspections of all roadway bridge and culvert structures in the city. The main objectives at that time were to determine the general condition of the city's bridges, identify urgent repair work, and obtain information for the initiation of a formalized maintenance program.

Table 1
City of Red Deer
Inventory of Bridges and Culverts

Structure ID No.	Structure Name	Age (Years)	Structure Type	No. of Spans	Replacement Cost (1989$)
1	Waskasoo Creek/32nd Street Culverts	12	Double 2400mm dia. CMP	1	$100,000.00
2	Piper Creek Culverts/32nd Street	17	Cast-in-place concrete boxes	1	$200,000.00
3	Waskasoo Creek/48th Avenue Bridge	25	Precast concrete girders	3	$500,000.00
4	Piper Creek Culverts/43rd Street	8	Double 3100X1980 mm CMP	1	$100,000.00
5	Waskasoo Creek 49th Avenue	15	Precast/prestressed conc.boxes	1	$500,000.00
6	Waskasoo Creek/Gaetz Avenue	32	Cast-in-place concrete arch	1	$500,000.00
7	Waskasoo Creek/82nd Avenue	24	Precast concrete girders	2	$500,000.00
8	Waskasoo Creek/52nd Ave. culvert	33	Cast-in-place concrete box	1	$200,000.00
9	45th Street/CPR yard overpass	25	Precast/prestressed concrete	11	$4,000,000.00
10	55th Street/CPR underpass	28	Steel plate girders	3	N/A
11	49th Avenue/Red Deer River Bridge	24	Precast P/S,P/T conc. girders	5	$5,000,000.00
12	67th Street/CPR Underpass	21	Precast P/S conc. box girders	4	N/A
13	60th Street/Gaetz Avenue Underpass	22	Concrete frame - T beams	3	$1,500,000.00
14	Waskasoo Creek/55th Street Bridge	32	Concrete frame - solid slab	1	$300,000.00
15	Waskasoo Creek/53rd Street Bridge	25	Precast concrete girders	3	$400,000.00
18	Ross Street/Waskasoo Ck. Bridge NB	9	Precast/prestressed concrete	1	$750,000.00
18	Ross Street/Waskasoo Ck. Bridge SB	24	Precast/prestressed concrete	1	$750,000.00
19	Gaetz Avenue/Red Deer River Bridge	43	Built-up steel haunched girder	6	$5,000,000.00
20	Spruce Drive Retaining Wall	Unknown	Concrete block	N/A	N/A
21	Taylor Drive/Red Deer River Bridge	10	Precast/prestressed concrete	5	$4,000,000.00
22	Fairbanks Pedestrian Bridge	11	Precast/prestressed concrete	3	$400,000.00

Total # structures = 19 Average age = 22 years Total Replacement Value=$24,700,000.00
SAY = $25,000,000.00

The first bridge maintenance report, which included an inventory of all the City's roadway bridges and culverts, was completed in 1977. By 1979, the program involved detailed inspections and reporting every year. Bridge maintenance reports were updated annually and budgets were being planned for a 5-year period.

Over the years, the bridge maintenance program has evolved into a management system particularly tailored to the specific requirements of the City's infrastructure. Maintenance budgets are still planned for a 5-year period. They are updated annually. Today, detailed inspections are performed on all structures and reports prepared every second year. Every other year, structures in relatively poor condition are inspected and an updated maintenance report is prepared which includes the 5-year maintenance plan and budget.

Inspection reports, prioritized maintenance repair work, and maintenance budgets are now computerized for easy manipulation and updating. Standard forms for bridge inspection have been developed for use in the field and for easy input of information into the computer.

THE BRIDGE MAINTENANCE PROGRAM

There are several separate components which comprise Red Deer's existing bridge maintenance program. Provided in the following text is a brief discussion of each aspect of the program.

Bridge Inventory

Apart from the general inventory of the City's structures, an inventory of components has been compiled for each structure. This inventory includes such items as type of girder, bearing, expansion joint, wearing surface, abutment, pier, slope protection, etc. Also included is such relevant information as year of construction, span lengths, posted load ratings, and the original designers.

This inventory has been conveniently incorporated into the inspection form to aid the inspector in the field. This inventory was compiled from information obtained from City records and later confirmed in the field.

The detailed bridge component inventory is kept current as the structures are modified. Normally the year when modifications are made is recorded on the inspection forms.

Visual Inspection

Visual inspections are completed for all structures every second year. Those structures which are showing signs of deterioration are inspected annually. Currently, four of the City's nineteen structures are inspected annually.

Inspection forms are based on the information obtained from the detailed inventory of the structure. In this way inspection forms are specifically tailored to suit each unique structure.

In the field, copies of the previous inspection reports are updated by a qualified bridge engineer. Inspections are usually performed from the top side of the superstructure to the substructures and components below.

Each component of the structure is reviewed and rated. This includes such items as the approaches to the structure, alignments, and channel ways. Rating is completed on the basis of general appearance as defined in Table 2. Condition ratings are used to assess the general performance of individual components of the bridge.

Table 2

Component Evaluation Rating

Rating	Description
DANGEROUS	Unsafe and life threatening condition,structure to be closed to public use
UNSAFE	Unsafe but not life threatening, immediate precautionary measures required
POOR	Poor condition and in need of prompt repair (within 1 year)
FAIR	Fair condition and in need of repair (within 2 to 3 years)
GOOD	Good condition, no repairs identified

Reid Crowther have reviewed several standards for component rating of bridge structures. Some of these standards include:

- the Alberta Transportation system which uses a 1 to 9 rating,
- the Ontario MTC system which uses a 1 to 6 rating, and
- the American FHWA system which uses a 0 to 9 rating.

There has been a considerable difference of opinion when it comes to evaluating the condition of bridge structures. Reid Crowther has elected to adopt this simplified method basically because it leaves the reader of the report with an immediate impression. It is important to keep in mind that not all readers of these reports have a good understanding of bridge structures.

During the inspection, the inspector is responsible to take record photographs of key components of the structure in order to be able to visually evaluate the rate of deterioration of components with time. The inspector, in conjunction with the senior bridge engineer will also evaluate the need for additional inspections or testing.

Additional Inspection, Testing, and Analysis

The requirement for additional inspection, testing, or analysis arises when there are visual indications that a certain component of the bridge structure is deteriorating and a more precise assessment of the state of deterioration or the adequacy of the structure is desired.

These additional services involve the following:

1. Non-destructive materials testing, such as:
    - half-cell corrosion potential survey
    - concrete covermeter survey
    - chain-drag delamination survey
    - radiographic or ultrasonic testing of steel
2. Destructive materials testing, such as:
    - concrete compression tests
    - coring of deck slabs for air and chloride tests
3. Visual inspections, such as:
    - crack mapping
    - visual monitoring of corroding elements
    - taking of field measurements (surveys)
4. Structural analysis and load rating

Non-destructive and destructive testing and visual inspections are generally used to aid both in the preparation of repair schedules and in assessing the extent of the repair program more accurately. For example, a typical concrete deck rehabilitation study will generally include any combination of the following tests and surveys:

- half-cell corrosion potential survey
- concrete covermeter survey
- chain-drag delamination survey
- concrete compression tests
- coring of deck slabs for air and chloride tests
- crack mapping
- taking of field measurements (surveys)

Structural analysis or load rating is usually required when deterioration of a structural element has sufficiently reduced its load-carrying capacity or if heavier vehicle loads are to be used on the structure than those for which they were originally designed.

Prioritization of Repairs

Maintenance requirements will obviously not be the same for all bridges. Some will require routine maintenance and some immediate repairs. Because the funds made available for bridge maintenance activities are limited, the need to prioritize repairs is crucial so that the objectives of the program are met.

After the inspections, additional testing, or analysis have been completed, the results are reviewed and a master list of maintenance items and repairs is prepared. Associated with each maintenance or repair item is the time frame within which its completion is recommended.

Maintenance activities are first prioritized based on observed need. The next procedure is to distinguish between work to be completed by City forces and work to be contracted out, as each has its own budget.

Cost estimates are then prepared for each activity for both City and contract work. Estimates for City work are based on information provided by the City concerning actual costs on previous work of similar nature. Estimates for contract work are prepared from information provided by experienced contractors, product suppliers, and from the firms' experience. Costs are estimated within an accuracy range of ±20 percent. Based on an average level of inspection and testing, it is difficult to be more accurate than this.

Previously prioritized maintenance and repair activities are re-evaluated in terms of cash flow over the 5-year period. Final adjustments are then made to the program with the aim of evening out the proposed expenditure on an annual basis.

Record Maintenance Drawings

Record maintenance drawings are a method of recording the maintenance history of each bridge structure. It consists of one drawing which typically shows a plan, elevation, typical section, alignment, and utilities. Recorded on these drawings is information pertaining to the original design, such as:

- the original designers
- the date of construction
- the design loads
- the original materials
- type and model of bearings and expansion joints

The maintenance history is also shown in a separate set of notes. This generally includes repairs which have been completed to the structure, not tasks arising from routine maintenance which is completed annually. The following information is usually recorded:

- the year of the repair
- the nature of the repair
- the engineer responsible for the repair

In some cases, these drawings are used to record measurements from monitoring programs such as deck elevations or expansion joint gaps. Also shown are any posted load restrictions andthe in which year they were imposed.

Record maintenance drawings are reviewed or updated annually. Reduced copies are included in the maintenance report and full-size prints are submitted to the Engineering Department.

Reporting

Reports are prepared in two volumes. Volume 1 contains the body of the report, and Volume 2 the record photographs. Draft reports are submitted first for City review and comment. Based on input regarding budgets, scheduling and maintenance activities, the final report is then completed and the policies stated therein implemented.

MAINTENANCE AND REHABILITATION WORK

Bridge maintenance and rehabilitation work in Red Deer is completed by City forces with the Public Works Department and by bridge contractors experienced with this type of work.

The type of bridge maintenance activities generally completed by City forces includes:

- washing curbs, barriers, bridge decks and deck drains,
- cleaning out expansion joints seals and joint drains,
- minor concrete patch repairs,
- sealing cracks and joints in asphalt overlays, and
- cleaning debris from around abutment seats, the tops of piers, slope protection and channel ways.

The types of bridge maintenance activities generally contracted out by the City includes:

- major concrete patch repairs,
- epoxy injection of concrete cracks,
- bearing refurbishment and replacement,
- replacement of expansion joints,
- application of concrete sealers to decks and curbs, and
- installation of joint sealants.

It is important that those contractors invited to bid on the work have previous experience with the proposed repair procedures and the specified products.

BRIDGE MAINTENANCE COSTS

The information included in this section has been provided by the City of Red Deer. It has been derived from an aggregate total of actual maintenance expenditures recorded between 1980 and 1989 for engineering and, City and contract maintenance. The breakdown of expenditure on a per-category basis was estimated based on budget information provided in bridge maintenance reports and actual expenses recorded by the City and Reid Crowther. City maintenance from 1980 to 1984 was estimated on the basis of a minimum amount of routine maintenance, because budget information was not available.

As a means of evaluating the extent of the money spent on bridge maintenance and rehabilitation, it is common to compare annual expenditures to the total replacement value of the entire stock of structures. Table 3 gives a summary of annual maintenance and rehabilitation budgets separated into three categories (engineering fees, City maintenance operation expenses, and contract maintenance and repair expenses) along with total annual budgets.

The total replacement value of Red Deer's structures, in 1989 dollars, is estimated at approximately $25 million. A breakdown of this estimate has been shown in Table 1 containing the inventory of City structures.

The following conclusions can be drawn from this summary:

- the amount of data currently available is relatively small, therefore the confidence level of statistical analyses is considered low, though still useful,
- the average annual engineering expenditure is fairly constant, excluding any given year containing major rehabilitation work,
- the level of maintenance provided by City forces has increased to a more substantial level of activity, and
- contract maintenance and rehabilitation activities involve the largest expenditure in the bridge maintenance program and engineering and City maintenance expenses are of a similar order of magnitude.

Table 3

City of Red Deer

Summary of Bridge Maintenance Expenses ($x1000)

Year	Engineering	City Maintenance	Contract Maint./ Repairs	Total
1980	30.0	13.2	253.8	297.0
1981	40.0	13.2	348.8	402.0
1982	40.0	13.2	333.8	387.0
1983	16.0	13.2	54.8	84.0
1984	15.0	13.2	51.8	80.0
1985	22.8	16.2	20.0	59.0
1986	13.5	20.0	55.5	89.0
1987	22.0	17.0	46.0	85.0
1988	21.5	47.5	0.0	69.0
1989	94.0	31.9	621.0	746.9
Total	314.8	198.6	1,785.5	2,298.9
Cost/year	$31,480.00	$19,860.00	$178,550.00	$229,890.00
Cost/year/structure	$1,656.84	$1,045.26	$9,397.37	$12,099.47
Cost/year/replacement	0 .13%	0.08%	0.71%	0.92%

The total replacement value of Red Deer's structures, in 1989 dollars, is estimated at approximately $25 million. A breakdown of this estimate has been shown in Table 1 containing the inventory of City structures.

The following conclusions can be drawn from this summary:

- the amount of data currently available is relatively small, therefore the confidence level of statistical analyses is considered low, though still useful;
- the average annual engineering expenditure is fairly constant, excluding any given year containing major rehabilitation work;
- the level of maintenance provided by City forces has increased to a more substantial level of activity; and

- contract maintenance and rehabilitation activities involve the largest expenditure in the bridge maintenance program, and engineering and City maintenance expenses are of a similar order of magnitude.

The most important fact to consider is that the average cost of the program to date is 0.92 percent of the total replacement value of the entire stock of structures. In the March 1987 edition of Public Roads magazine there appears an article written by Charles F. Galambos entitled "Bridge Design Maintenance and Management" in which he states the following:

> "A rule of thumb for maintenance of an acceptable level of service when the bridge stock is mature (no more new highway systems are being added) is that 2 percent of the replacement value of the entire stock must be spent annually for bridge maintenance rehabilitation and replacement."

In a paper presented by Ted Belke,of Alberta Transportation - Bridge Branch, entitled "Feasibility of Bridge Rehabilitation", he states:

> "Considering the substantial backlog of work now required in most jurisdictions, budgets of 1% of bridge replacement value for bridge maintenance and rehabilitation and a further 1% for bridge replacements, as suggested by Mr. Galambos, appears reasonable."

It has also been the experience of Reid Crowther through similar work completed in other areas of Alberta and in other provinces in western Canada, that 1 percent of replacement cost is typically required annually for bridge maintenance and rehabilitation.

It appears that the amount spent to date by the City of Red Deer on bridge maintenance and rehabilitation is less than that recommended as an acceptable level. Based on the average age of the City's structures, this is good news for the City of Red Deer; however, based on the current trend in the need to rehabilitate, this average annual cost may continue to increase slightly over the next few years.

Another important aspect of this maintenance management system is the ability to monitor annual expenditures on a per-structure basis in order to determine which structures are becoming prohibitively expensive to maintain. This way of budgeting for replacement can be completed well in advance, thereby potentially eliminating the situation where the City can obtain funds under urgent circumstances.

Table 4 is a summary of annual expenditures on a per-category basis, along with the average total cost per year per structure. As a guideline, those structures whose average annual costs exceed that for the average of the total stock combined are considered to be relatively expensive to maintain.

Table 4
City of Red Deer
Summary of Bridge Maintenance Expenses ($)

Structure No.	Engineering	City Work	Contract Work	Total	Cost/Year
1	4,100.00	3,000.00		7,100.00	$1,014.29
2	5,600.00	16,700.00	15,000.00	37,300.00	5,328.57
3	58,600.00	6,200.00	450,000.00	514,800.00	73,542.86*
4	4,600.00	3,200.00	1,000.00	8,800.00	1,257.14
5	4,100.00	3,700.00		7,800.00	1,114.29
6	6,900.00	3,200.00	12,000.00	22,100.00	3,157.14
7	4,100.00	11,200.00		15,300.00	2,185.71
8	4,100.00	5,800.00		9,900.00	1,414.29
9	17,600.00	15,700.00	105,000.00	138,300.00	19,757.14*
10	4,100.00	4,400.00		8,500.00	1,214.29
11	7,100.00	7,300.00	28,000.00	42,400.00	6,057.14
12	4,600.00	3,400.00	1,000.00	9,000.00	1,285.71
13	6,600.00	4,700.00	13,500.00	24,800.00	3,542.86
14	25,600.00	10,200.00	124,000.00	159,800.00	22,828.57*
15	8,600.00	11,700.00		20,300.00	2,900.00
18	14,600.00	4,700.00	95,000.00	114,300.00	16,328.57*
19	4,600.00	12,300.00	1,500.00	18,400.00	2,628.57
20	4,100.00	1,700.00	19,000.00	24,800.00	3,542.86
21	12,100.00	9,300.00	35,000.00	56,400.00	8,057.14
22	5,100.00	3,000.00	5,000.00	13,100.00	1,871.43
Total	206,800.00	141,400.00	905,000.00	1,253,200.00	179,028.57

* Annual cost exceeds average

This information has been obtained from budgets for work completed, not the actual expenditure. This is because the City's accounting system was not set up to keep track of expenses on a per-structure basis.

The summary table indicates that four structures fall within this category of being costly to maintain. Of these, structure #3 is scheduled for major rehabilitation or replacement in 1989; structure #9 is scheduled for demolition within the next 3 to 4 years; structure #14 is scheduled to have a sidewalk added, for functional reasons; and structure #18 has required considerable repairs over the past few years.

Though quantitative results are not available from this bridge maintenance program, experience has shown that maintenance costs are generally paid back by significant savings resulting from the implementation of the program.

Initially, as in many other urban areas, the need for spending to preserve bridges and culverts was not perceived by the general public and municipal decision-makers within the City of Red Deer to be a high priority. Funding to initiate the program was small, however, over the past few years. This perception has been changing, and adequate funding is now being made available. Funding from the Alberta government, as a result of the existing cost-sharing programs for major rehabilitation projects, has helped the City considerably.

CONCLUSIONS

As experienced in other urban centres in Canada, the City of Red Deer has realized that, without a well-planned and properly managed bridge maintenance program, its bridge structures will deteriorate at a fast rate, resulting in potential dangers to the general public using the road network, inconvenience to the public as a result of interruptions, and difficulties in managing finances as a result of unexpected large expenditures when serious problems arise.

Since the inception of the bridge maintenance program in 1976, the City has been able to increase its level of confidence concerning the adequacy of their structures, develop good routine and preventative maintenance practices to prolong the useful life of their structures, plan budgets well in advance to maintain a consistent cash flow, and begin to keep accurate records of useful information pertaining to their structures.

The average annual expenditure by the City of Red Deer on bridge maintenance and rehabilitation is below the minimum accepted standard of 1 percent of the total replacement value of the entire stock of structures. This is an indication that the City's bridges and culverts are, generally, in good condition. This can be attributed partly to the City's early development of a bridge maintenance program in which preventive maintenance activities are performed, partly to the City's moderate application of de-icing salts in the winter, and partly to the moderate level of service which these structures encounter.

The general public and municipal decision-makers within the City of Red Deer are becoming more receptive to the pressing need for adequate funding to protect this fundamental aspect of its urban infrastructure. This level of funding appears to be available today. It is currently the perception of the City that there is value in money spent today on bridge maintenance and that the current program appears to be providing an adequate level of service.

The City of Red Deer should be commended for their foresight and determination in initiating and implementing the current bridge maintenance program. Reid Crowther have been pleased to have been able to assist the City in achieving its objectives.

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DECISION-MAKING IN BRIDGE MANAGEMENT BY USING MICROCOMPUTERIZED DATABASES

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ABSTRACT

A microcomputer-based bridge management system was used to inventory and evaluate a sample population of bridges in the Province of British Columbia, using the Bridge Rehabilitation, Inventory and Maintenance Management System (BRIMMS). The user-defined, computer-generated reports produced in the project included bridge condition, service level, traffic importance, urgency level, optimal workplans, workplan budgets, and bridge population condition summaries. The paper describes the project activities of data collection, fieldwork, data entry, computer report generation, and report evaluation. The paper also outlines the system features and criteria contained in the BRIMMS software package.

RÉSUMÉ

Le système de gestion des ponts par micro-ordinateur (BRIMMS) a permis de répertorier et d'évaluer un échantillon de ponts en Colombie-Britannique. En effet, des relevés produits par ordinateur dans le cadre du projet renseignent sur l'état des ponts, le niveau de service, l'importance du trafic, le niveau d'urgence, les plans de travail.et budgets optimaux, en plus de fournir des sommaires d létat de l'ensemble des ponts. Le document traite de la collecte de données, des travaux à pied d'oeuvre, de l'entrée des données, de la production de rapports d'ordinateur de même que de l'évaluation des rapports. En outre, il fait ressortir les caractéristiques et critères d'utilisation du logiciel BRIMMS.

INTRODUCTION

The Bridge Engineering Branch of the Ministry of Transportation and Highways, British Columbia, is responsible for maintaining more than 3,000 bridges throughout the province. The majority of these bridges are of steel or concrete construction, or both. The remainder are timber structures.

For 3,000 bridges dispersed over a large area, it is important to establish uniform inspection and assessment criteria as well as an optimal basis of assigning funds for effective life-cycle maintenance. Improved management techniques in these functions result in a more effective use of bridge maintenance budgets.

A sample population of 40 bridges in Greater Vancouver was identified for demonstration of the use of a microcomputer-based bridge management system (BRIMMS). Ministry staff assembled the bridge inventory data required in the BRIMMS databases. Delcan Corporation staff carried out the fieldwork to obtain the required bridge component condition ratings. Delcan staff then carried out data entry directly from standard BRIMMS Inventory and Fieldwork Forms.

Using the BRIMMS databases, Delcan then produced a series of computer-generated reports. These reports displayed the relationships between key decision-making factors in bridge maintenance management. A few sample reports are reproduced in the Appendix.

PROJECT OBJECTIVES:

- to demonstrate the effectiveness of an up-and-running BRIMMS, previously developed by Delcan;
- to establish a complete and easily accessible computerized bridge inventory of the selected sample bridge population;
- to prioritize bridge rehabilitation and maintenance work programs based on key parameters, including condition rating, urgency of remedial action, service of level rating and traffic importance;
- to provide a computerized format for itemizing and producing budgets for cost-effective workplans;
- to evaluate the short- and long-term impacts of alternative workplans; and
- to demonstrate a methodology to optimize the life-cycle maintenance of the bridge population in British Columbia.

DESCRIPTION OF BRIMMS FEATURES

In BRIMMS, the bridge inventory is accommodated in four subsystems called Physical Inventory, Traffic, Bridge Condition, and Service Level. The fifth subsystem, Program Planning, then processes the inventory data to produce a series of inventory and planning reports. The sixth subsystem, File Utilities, contains the user's manual and various operating procedures.

The rest of this paper outlines the main features of BRIMMS, illustrated by its application to the British Columbia Demonstration Project.

Fifty-one reports and computer screen printouts were produced in the British Columbia Demonstration Project. All of these were generated on the basis of real data and actual observations obtained in the fieldwork performed on the sample population of 40 bridges. In addition to these reports, it is possible to get a hard copy of any current screen in BRIMMS.

Bridge Condition Rating (BCR)

On a span-by-span basis, each component is given a 2-character rating such as P2 or F5. The first character is the material condition (good, fair, poor, very poor) and the second is the urgency of remedial action (zero - immediate, 1 - within one year, 2 - within 2 years, 5 - within 5 years, and N - no action required within 5 years). An alternative section of BRIMMS automatically reports any urgency for remedial action based on observed physical defects in components as related to the weighted criticality of these components in the structure.

The material condition and urgency ratings are converted to a numeric Component Condition Rating (CCR) on a scale of zero to 100 by means of a conversion program. On this basis, the Component Group Rating (CGR) and the Bridge Condition Rating (BCR) are then computed.

Bridge Service Rating (BSR)

The bridge service rating includes the following elements: bridge traffic barriers, flooding potential, hazardous utilities, horizontal curvature, load capacity, narrowing of approaches, number of lanes, number of sidewalks, traffic opening under bridge, vertical clearance over and under bridge, vertical curvature, and width of lanes.

For each of these elements there is an actual, a desirable, and a mandatory service level. For example, an actual lane width may be 3.30 m, the mandatory lane width 3.00 m and the desirable lane width 3.73 m. Individual elements are assigned service level point reductions computed by algorithm, falling into one of the following three categories:

1. Actual condition equals or is better than desirable: no point reduction.
2. Actual condition is worse than the mandatory level: maximum point reduction.

3. Actual condition is equal to or better than the mandatory level but less than the desirable level: intermediate point reduction.

The BSR is determined by summing all the point reductions and subtracting them from 100. If the total point reduction exceeds 100 then the service rating would be zero.

Traffic Importance and Status Factors

The traffic significance factor is computed by algorithm for all bridges in the population, based on data extracted from 'traffic' subsystem. The key parameters are AADT and special traffic categories such as bus or LRT routes.

The status factor enables the user to subjectively increase or decrease the ranking of a given bridge or set of bridges. A higher status ranking may be influenced by heritage considerations, network criticality, political overrides and non-recurring funding. A lower status ranking may be due to future bridge closure or replacement.

Overall Bridge Rating

The Overall Bridge Rating (OBR) is determined by summing the BCR and the BSR in user-specified proportions. The factored bridge ratings (FCR, FSR, and OFR) are obtained by applying the traffic significance factors and status factors to the BCR, BSR, and OBR ratings.

Glossary of BRIMMS Abbreviations

BCR - Bridge Condition Rating
BSR - Bridge Service Rating
CCR - Component Condition Rating
CGR - Component Group Rating
FCR - Factored Bridge Condition Ranking
FSR - Factored Bridge Service Ranking
OBR - Overall Bridge Rating
OFR - Overall Factored Bridge Ranking
OPR - Overall Population Rating
PCR - Bridge Population Condition Rating
PSR - Bridge Population Service Rating
ROI - Return on Investment

Initial Bridge Ranking

For the purpose of planning rehabilitation work, it is important to identify the bridges which require the most urgent attention. The shortlisting of critical bridges is achieved in BRIMMS by means of an initial bridge ranking. This ranking is based an the inventory data and follows the criteria listed below. It does not consider actual workplans or costs. Its main purpose is to filter the large number of bridges in the database to identify a shortlist of candidates for repair, rehabilitation, upgrading, or replacement. The six alternative bridge ranking criteria are: BCR, BSR, FCR, FSR, OBR, and OFR. The system operates on the basis of OFR by default. (FCR, FSR, and OFR are rankings, not ratings, since only their relative and not their absolute values are relevant.) The selection of the appropriate ranking criterion out of the six alternatives is at the discretion of the planner.

In the Demonstration Project, a shortlist of nine out of the sample population of 40 bridges was identified by examining the initial bridge ranking report. The shortlist was defined by bridges with a BCR of less than 30 (out of 100 possible points). The same shortlist of nine bridges resulted from the OBR, which is a weighted combination of BCR and BSR. Work programs are not normally prioritized purely on the basis of service level unless the bridges in question are grossly deficient in function.

Remedial Workplans and Life-Cycle Analysis

Once the planner selects the shortlist of bridges based on the appropriate initial bridge ranking criteria, BRIMMS will generate the remedial workplans for these bridges. It is in these workplans for shortlisted bridges that remedial action, service level upgrade, costing, and life-cycle analyses are developed. Life-cycle analysis is performed for two purposes:

1. to rate various remedial action or no-action scenarios against one another and
2. to enable the computer to generate workplans automatically.

BRIMMS calculates life-cycle costs based on five categories of remedial action. These are minor repairs, moderate repairs, major repairs (rehabilitation), replacement, or no action. The computer will automatically choose the least life-cycle cost, component by component and span by span. It will then give present remedial action costs and equivalent uniform annual costs for each component and totals for each bridge and all bridges.

The site conditions prevailing at the location of each required repair are listed in various reports under such headings as AADT, Number of Lanes, Impact of Repairs on Traffic, and Road Class. These conditions will influence the grouping of repair categories in the workplans and also the scheduling of the work. The user can override the automatically generated workplans based on his or her review of site-specific conditions and any other pertinent factors. The resulting modified workplans will then reside in the system and be subject to financial analysis.

Supplementary Cost Items

There is provision in the program for recording supplementary cost items, such as complete bridge replacement, deck widening, instrumented condition surveys, engineering evaluation, detours, or other items which cannot be automatically priced by the computer and entered into the workplans.

Cost Benefit and Return On Investment Rankings

Once the workplans have been generated, a true picture of maintenance priorities can be obtained by looking at the cost/benefit ratios and the Return On Investment (ROI) of the remedial actions proposed for each bridge.

ROI is defined as the yearly savings resulting from the workplans as a percentage of their cost. In general, if the ROI for a bridge is greater than the opportunity cost of money, then that bridge is a good candidate for remedial action.

This report provides an overview of the selected population of bridges. The Bridge Population Condition Rating (PCR) and the Bridge Population Service Rating (PSR) are computed by means of algorithms using the BCRs and BSRs. The Overall Population Rating (OPR) combines PCR and PSR in user-specified proportions. The PCR, PSR, and OPR ratings are a means of monitoring the status of the population in the course of time. At best, these ratings will increase; at worst, they will decrease. Hence, these parameters enable the monitoring of trends.

Population ratings are always computed by using these unfactored ratings in order to achieve valid year-to-year comparisons. These population rating algorithms take into account the economic value of each bridge in the population, based on its estimated present-day replacement cost.

In the Demonstration Project, the PCR for the 40 bridges selected was relatively high at 79.72 percent. A relatively low PSR reflected the fact that the design loading for many of the structures is less than that specified in the current standard. The reports regarding the bridge service level clearly showed the distinction between mandatory and desirable service level standards.

BRIMMS also predicts the future PCRs in 1 year's and 5 years' time by assuming that no maintenance or rehabilitation work is undertaken. To do this, it is necessary to calculate a master decay curve for the entire population. This master decay curve is obtained by using individual decay curves for all bridge components resident in the system. The Demonstration Project summary showed that the condition of the population of 40 bridges will degrade by over 10 percent within 5 years.

On the basis of any set of proposed maintenance workplans, BRIMMS computes the resulting new BCRs and the related new PCR. Ideally, the resulting new PCR should match or exceed the old PCR, otherwise either the bridge population is degenerating or the rehabilitation budget is inadequate.

Software

The entry and processing of BRIMMS data is handled by about 200 separate multi-color screen file images, numerous menu screens, and onscreen help listings. The version of BRIMMS used in the British Columbia project is based on over 13,000 lines of programming using Foxbase, a speed-enhanced clone of dBase III Plus. BRIMMS is user-friendly, and its application was readily understood by the Ministry's staff engineers.

Hardware

For the British Columbia Demonstration Project, the computer-generated BRIMMS reports were produced on an IBM-compatible AT microcomputer clone with a 640-kB memory capacity and a 40-MB hard disk. Every 1,000 bridges take up about 4 MB of space on the hard disk. Mainframe linkage by up- and downloading can be used when the inventory is extended to cover several thousands of bridges.

CONCLUSIONS

The British Columbia Demonstration Project shows how BRIMMS is used to establish an up-and-running bridge inventory for the purpose of economic bridge maintenance management on a province-wide basis. It also provides a methodology, through its microcomputer-based databases, for decision-making in bridge management. BRIMMS is an effective tool serving to evaluate and establish cost-effective life-cycle strategies for large populations of bridges.

ACKNOWLEDGMENTS

The Ministry of Transportation and Highways of the Province of British Columbia which permitted reference to the Demonstration Project in this paper.

APPENDIX

BRIMMS LISTING REPORT

Bridge Rehabilitation, Inventory & Maintenance Management System

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BC MINISTRY OF TRANSPORTATION AND HIGHWAYS
Friday, October 28, 1988
PILOT PROJECT BRIDGE POPULATION

THIS REPORT INCLUDES BRIDGES WHICH SATISFY THE FOLLOWING CONDITIONS:

1. BRIDGE BUILT BETWEEN 1900 AND 1980.
2. BRIDGE CONDITION RATING BETWEEN ZERO AND 97.
3. NO CONCRETE BRIDGES.

BRIDGE NUMBER	BRIDGE NAME	NUMBER OF SPANS	BRIDGE LENGTH	BRIDGE CONDITION RATING	SUPERSTRUCTURE MATERIAL
1012	MARINE DR OVERPASS	2	12.200	30	WELDED STEEL
1401	CAPILANO	5	184.500	79	REINFORCED CONCRETE
1516	FERN ST U/P	3	54.200	10	PRESTRESSED CONCRETE
1585	MOSQUITTO CREEK	9	150.580	82	REINFORCED CONCRETE
1619	HORSESHOE BAY O/H	6	116.000	30	BOLTED STEEL
1665E	CNR OVERPASS	8	132.110	86	REINFORCED CONCRETE
1665W	CNR OVERPASS #2	8	118.920	79	REINFORCED CONCRETE
1666E	BOUNDARY OVERPASS	5	106.700	89	PRESTRESSED CONCRETE
1672	SPROTT STREET UNDERPASS	8	156.800	85	PRESTRESSED CONCRETE
1677N	BRUNETTE RIVER BRIDGE	4	100.300	86	PRESTRESSED CONCRETE
1677S	BRUNETTE RIVER BRIDGE	4	100.700	86	PRESTRESSED CONCRETE
1678N	CNR OVERPASS	6	108.700	87	PRESTRESSED CONCRETE
1678S	CNR OVERPASS	6	113.500	90	PRESTRESSED CONCRETE
2338	ARGYLE AVE OVERPASS	3	47.600	97	WELDED STEEL
2339	HORSESHOE BAY UNDERPASS	5	105.200	97	WELDED STEEL
2340	SQUAMISH UNDERPASS	3	74.500	96	WELDED STEEL
2341	EAGLE RIDGE DR UNDERPASS	3	50.600	97	WELDED STEEL
2343	CAULFIELD DR UNDERPASS	3	50.600	96	WELDED STEEL
2346	AL MONDEL OVERPASS	3	44.380	96	WELDED STEEL
2347	WESTMOUNT RD OVERPASS	3	68.660	96	WELDED STEEL
2348W	TWENTY FIRST ST OVERPASS	3	56.800	88	WELDED STEEL
2500	CAPILANO RIVER BRIDGE	7	149.600	89	WELDED STEEL

FIGURE 1

BRIMMS LISTING REPORT

Bridge Rehabilitation, Inventory & Maintenance Management System
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BC MINISTRY OF TRANSPORTATION AND HIGHWAYS
Friday, October 28, 1988
PILOT PROJECT BRIDGE POPULATION

THIS REPORT INCLUDES BRIDGES WHICH SATISFY THE FOLLOWING CONDITIONS:

1. BRIDGE CONDITION RATING BETWEEN ZERO AND 97.
2. CONCRETE BRIDGES.
3. BRIDGE BUILT BETWEEN 1900 AND 1980.

BRIDGE NO.	BRIDGE NAME	NO. OF SPANS	BRIDGE LENGTH	BRIDGE COND. RATING	DECK GROUP COND. RATING	SUPERSTRUCTURE GROUP COND. RATING	SUBSTRUCTURE GROUP COND. RATING	OTHER COMPONENT GROUP RATING (STRUCTURAL)
1586	LYNN VALLEY OVERPASS	3	46.100	20	96	100	20	100
1663E	FIRST AVE. OVERPASS	4	56.900	30	30	100	81	100
1663W	FIRST AVE OVERPASS	4	56.900	20	20	100	20	100
1664E	LOUGHEED OVERPASS	4	57.400	20	20	20	20	100
1664W	LOUGHEED OVERPASS	4	55.400	90	82	100	100	100
1667	LLYDES DALE UNDERPASS	5	92.590	90	82	100	100	100
1671	DOUGLAS RD. OVERPASS	4	85.400	20	82	100	20	100
1675	TORMWNT AVE OVERPASS	4	78.480	20	89	87	20	100
1676	CARIBOO ST UNDERPASS	4	56.400	86	76	100	100	100

FIGURE 2

BRIMMS LISTING REPORT

Bridge Rehabilitation, Inventory & Maintenance Management System

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BC MINISTRY OF TRANSPORTATION AND HIGHWAYS
Friday, October 28, 1988
PILOT PROJECT BRIDGE POPULATION

THIS REPORT INCLUDES BRIDGES WHICH SATISFY THE FOLLOWING CONDITIONS:

1. BRIDGE BUILT BETWEEN 1900 AND 1980.
2. STEEL BRIDGES.
3. BRIDGE CONDITION RATING BETWEEN ZERO AND 97.

BRIDGE NO.	BRIDGE NAME	NO. OF SPANS	BRIDGE LENGTH	BRIDGE COND. RATING	DECK GROUP COND. RATING	SUPERSTRUCTURE GROUP COND. RATING	SUBSTRUCTURE GROUP COND. RATING	OTHER COMPONENT GROUP RATING (STRUCTURAL)
1012	MARINE DR OVERPASS	2	12.200	30	30	30	75	100
1516	FERN ST U/P	3	54.200	10	30	30	10	100
1619	HORSESHOE BAY O/H	6	116.000	30	77	100	30	100
1665E	CNR OVERPASS	8	132.110	86	75	100	100	100
1665W	CNR OVERPASS #2	8	118.920	79	63	100	100	100
1666E	BOUNDARY OVERPASS	5	106.700	89	82	100	92	100
1672	SPROTT STREET UNDERPASS	8	156.800	85	74	100	100	100
1677N	BRUNETTE RIVER BRIDGE	4	100.300	86	76	100	100	100
16775	BRUNETTE RIVER BRIDGE	4	100.700	86	76	100	100	100
1678N	CNR OVERPASS	6	108.700	87	78	100	100	100
1678S	CNR OVERPASS	6	113.500	90	82	100	100	100
2338	ARGYLE AVE OVERPASS	3	47.600	97	100	100	100	100
2339	HORSESHOE BAY UNDERPASS	5	105.200	97	96	100	100	100
2340	SQUAMISH UNDERPASS	3	74.500	96	96	100	100	100
2341	EAGLE RIDGE DR UNDERPASS	3	50.600	97	96	100	100	100
2343	CAULFIELD DR UNDERPASS	3	50.600	96	96	100	100	100
2346	AL MONDEL OVERPASS	3	44.380	96	96	100	100	100
2347	WESTMOUNT RD OVERPASS	3	68.660	96	96	100	100	100
2348W	TWENTY FIRST ST OVERPASS	3	56.800	88	82	100	97	100
2500	CAPILANO RIVER BRIDGE	7	149.600	89	84	100	100	100

FIGURE 3

BRIMMS LISTING REPORT

Bridge Rehabilitation, Inventory & Maintenance Management System

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BC MINISTRY OF TRANSPORTATION AND HIGHWAYS
Friday, October 28, 1988
PILOT PROJECT BRIDGE POPULATION

THIS REPORT INCLUDES BRIDGES WHICH SATISFY THE FOLLOWING CONDITIONS:

1. BRIDGE CONDITION RATING BETWEEN O AND 95.
2. CONCRETE BRIDGES
3. NUMBER OF SPANS BETWEEN 1 AND 5.
4. BRIDGE LENGTH BETWEEN ZERO AND 80.

THE NUMBER OF BRIDGES COUNTED FOR THE FIRST CONDITION IS 24

THE NUMBER OF BRIDGES COUNTED FOR THE FIRST 2 CONDITIONS IS 9

THE NUMBER OF BRIDGES COUNTED FOR THE FIRST 3 CONDITIONS IS 9

THE NUMBER OF BRIDGES COUNTED FOR THE FIRST 4 CONDITIONS IS 7

FIGURE 4

BRIMMS LISTING REPORT

Bridge Rehabilitation, Inventory & Maintenance Management System
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BC MINISTRY OF TRANSPORTATION AND HIGHWAYS

Friday, October 28, 1988

PILOT PROJECT BRIDGE POPULATION
SORTED BY BRIDGE NUMBER

NO SHORTLISTING CONDITIONS ARE SPECIFIED FOR THIS REPORT.

BRIDGE NUMBER	BRIDGE NAME	SUPERSTRUCTURE TYPE	SUPERSTRUCTURE MATERIAL	BRIDGE LENGTH	NUMBER OF SPANS	BRIDGE CONDITION RATING
1012	MARINE DR OVERPASS	SLAB ON STEEL BEAM	WELDED STEEL	12.200	2	30
1401	CAPILANO	OPEN SPANDREL ARCH	REINFORCED CONCRETE	184.500	5	79
1428	NELSON CREEK BRIDGE	SLAB ON CONCRETE GIRDER	REINFORCED CONCRETE	208.500	4	98
1516	FERN ST U/P	SLAB ON CONCRETE GIRDER	PRESTRESSED CONCRETE	54.200	3	10
1585	MOSQUITTO CREEK	OPEN SPANDREL ARCH	REINFORCED CONCRETE	150.580	9	82
1586	LYNN VALLEY OVERPASS	CONCRETE BEAM AND SLAB	REINFORCED CONCRETE	46.100	3	20
1595	MOUNTAIN HWY UNDERPASS	SLAB ON CONCRETE GIRDER	STONE MASONRY	22.450	1	100
1619	HORSESHOE BAY O/H	SLAB ON STEEL BEAM	BOLTED STEEL	116.000	6	30
1663E	FIRST AVE. OVERPASS	CONCRETE BOX GIRDER	WELDED STEEL	56.900	4	30
1663w	FIRST AVE OVERPASS	CONCRETE BOX GIRDER	WELDED STEEL	56.900	4	20
1664E	LOUGHEED OVERPASS	CONCRETE BOX GIRDER	REINFORCED CONCRETE	57.400	4	20
1664W	LOUGHEED OVERPASS	CONCRETE BOX GIRDER	REINFORCED CONCRETE	55.400	4	90
1665E	CNR OVERPASS	SLAB ON CONCRETE GIRDER	REINFORCED CONCRETE	132.110	8	86
1665W	CNR OVERPASS #2	SLAB ON CONCRETE GIRDER	REINFORCED CONCRETE	118.920	8	79
1666E	BOUNDARY OVERPASS	SLAB ON CONCRETE GIRDER	PRESTRESSED CONCRETE	106.700	5	89
1666W	BOUNDARY OVERPASS	SLAB ON CONCRETE GIRDER	PRESTRESSED CONCRETE	106.700	5	100
1667	LLYDES DALE UNDERPASS	CONCRETE BOX GIRDER	PRESTRESSED CONCRETE	92.590	5	90
1669	CARLETON OVERPASS	CONCRETE BOX GIRDER	PRESTRESSED CONCRETE	104.000	6	100
1671	DOUGLAS ROAD OVERPASS	CONCRETE BOX GIRDER	PRESTRESSED CONCRETE	85.400	4	20
1672	SPROTT STREET UNDERPASS	SLAB ON CONCRETE GIRDER	PRESTRESSED CONCRETE	156.800	8	85
1675	TORMOUNT AVE OVERPASS	CONCRETE BOX GIRDER	PRESTRESSED CONCRETE	78.480	4	20
1676	CARIBOO ST UNDERPASS	CONCRETE BOX GIRDER	PRESTRESSED CONCRETE	56.400	4	86
1677N	PRUNETTE RIVER BRIDGE	SLAB ON CONCRETE GIRDER	PRESTRESSED CONCRETE	100.300	4	86
1677S	BRUNETTE RIVER BRIDGE	SLAB ON CONCRETE GIRDER	PRESTRESSED CONCRETE	100.700	4	86
1678N	CNR OVERPASS	SLAB ON CONCRETE GIRDER	PRESTRESSED CONCRETE	108.700	6	87

FIGURE 5

WHAT SHOULD WE DO ABOUT EXISTING BUILDINGS WHEN WE REVISE OUR BUILDING CODES

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Robert Halsall and Associates Limited
Toronto, Ontario

ABSTRACT

Our building codes are written with the objective of ensuring life safety. They are drafted by committees of researchers, designers and public officials.

The early versions were very short and simple. They were related to the designs and construction materials that had been used in the bulk of the stock of buildings as then existed.

It would generally not be difficult to check a building designed and built, say, in the 1920s, for conformance with the 1953 National Building Code. If upgrading were required it would usually be justified in easily understood terms.

Today, codes have become technically and legally far more complicated.

Virtually no buildings constructed even ten years ago would meet all the requirements of now current codes.

How do we agree about the significance of non-compliance with the latest codes? When do we insist on upgrading? How do we deal with the economic reality that it may cost very little to incorporate a new code requirement into the design of a new building, whereas the cost of modifying an existing structure may be extremely high?

The paper sets out some questions for discussion and suggests some approaches that may be taken.

RÉSUMÉ

Les codes du bâtiment visent à assurer la sécurité des gens qui occupent nos immeubles. Ils sont le fruit du travail de comités réunissant chercheurs, concepteurs et fonctionnaires.

Initialement, ils étaient très brefs et très simples, ayant trait aux concepts et matériaux de construction employés dans la majorité des immeubles en place.

Ainsi, il n'était généralement pas difficile de vérifier si un immeuble conçu et construit au cours des années 20, par exemple, était conforme aux normes du Code national du bâtiment paru en 1953. Advenant la nécessité d'une modernisation, celle-ci pouvait habituellement être étayée sur des motifs faciles à comprendre.

Les codes en vigueur aujourd'hui sont toutefois beaucoup plus compliqués au plan tant juridique que technique.

À peu près aucun des immeubles construits il y a même dix ans à peine satisferait à toutes les exigences des codes présentement en vigueur.

Alors comment se mettre d'accord sur la gravité d'un manquement aux derniers codes parus? Quand exiger une modernisation? Comment tenir compte du fait que, si l'intégration d'une nouvelle exigence à la conception d'un immeuble neuf peut ajouter très peu aux frais engagés, la modification d'une structure en place peut, en revanche, être très coûteuse?

L'exposé soulève divers points de discussion et suggére quelques solutions possibles.

PARKING GARAGE DETERIORATION - A MUNICIPAL RESPONSE

E. Yaman Uzumeri
Building Commissioner
City of North York, Ontario

ABSTRACT

Throughout Canada, parking garage deterioration has become a major concern. Millions of square feet of decks are suspect and require structural repair. The problem appears to be much more acute in areas where de-icing salts are used during winter. It is widely accepted that corrosion of embedded steel in concrete, accelerated in the presence of salt, is the culprit for this very serious structural problem.

The City of North York with a population of 565,000 is a rapidly growing municipality. The majority of its development activity began 20 years ago. Today the City is in the middle of an unprecedented redevelopment process with many high rise commercial and residential buildings under construction. Value of construction in 1988 was $817 million.

It is estimated that there are 950 multi-level parking structures within the City. In 1982 it was decided that a comprehensive garage inspection and structural evaluation program must be developed. The program's objective is to insure that public safety is not jeopardized due to structural deterioration of parking structures resulting from owners' inability to maintain structural integrity of buildings.

The program got underway in 1983 and to date 456 garages have been inspected. Inspections consist of carrying out a detailed condition survey of the structure and sharing the information gathered with the owners so that appropriate steps may be taken to have the structure repaired. The condition survey is carried out during summer months by university students hired by the City for that purpose. It includes visual inspection, chain dragging, half-cell potential measurements and pachometer survey.

RÉSUMÉ

La détérioration des stationnements multiniveaux est devenue un problème majeur partout au Canada. L'état de millions de pieds carrés de surface de stationnement est

douteux et oblige à entreprendre d'importantes réparations structurales. Le problème semble par ailleurs beaucoup plus grave dans les régions où l'on épand du calcium en hiver. On reconnaît en général que la corrosion de l'acier armant le béton, qui est accélérée par l'action du calcium, est la principale cause de ce très grave problème structural.

North York compte 565 000 habitants. C'est une municipalité en pleine expansion, dont la croissance a, à vrai dire, commencé il y a 20 ans. La ville connaît une vague d'expansion sans précédent : on y construit beaucoup de tours d'habitation et de grands immeubles commerciaux. De fait, les projets de construction en cours y ont été évalués à 817 millions de dollars en 1988.

Selon toutes estimations, on trouve 950 stationnements multiniveaux à North York. En 1982, on a décidé qu'il fallait en faire une inspection et une évaluation structurale complète, afin de s'assurer que leur détérioration, par suite de l'incapacité de leurs propriétaires d'en préserver l'intégrité structurale, ne mettait pas la vie du public en danger.

Le programme a été lancé en 1983, et 456 parcs de stationnement ont été inspectés jusqu'ici. L'inspection comporte un examen poussé de l'état de la structure et la notification des résultats aux propriétaires afin que soient entreprises les réparations qui s'imposent. L'examen même des parcs de stationnement se fait en été et est confié à des étudiants d'université embauchés à cette fin par la Ville. Ils se fondent sur une visite des lieux, un essai de raclage à l'aide de chaînes, la mesure du potentiel de demi*cellules et une étude pachométrique.

NORTHWESTERN UTILITIES LTD.'S BARE-PIPE REPLACEMENT PROGRAM

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Northwestern Utilities Limited
Edmonton, Alberta

ABSTRACT

In response to the increasing maintenance costs of pipelines, Northwestern Utilities launched a $80.9 million program to replace all bare-steel mains and services in the City of Edmonton. The program, funded by Northwestern Utilities, is scheduled to take 10 years to complete. It will replace 200 km of mains and 18,3000 services. To date, 2 years into the program, 45 km of mains and 3,385 services have been replaced. A new replacement technique has been used to replace 23.4 km of mains and 2,166 services. This technique involves inserting a smaller diameter polyethylene pipe inside the existing steel pipe. System capacity is maintained by increasing the operating pressure to 100 kPa from 1.72 kPa. The insertion technique costs 64 percent less than direct burial because of the smaller amount of excavation, backfilling, and restoration required. Direct burial is required on the remainder of the mains and services because of capacity requirements, i.e., the existing pipe is too shallow or the existing location is unsuitable.

RÉSUMÉ

Devant la hausse du coût d'entretien des pipelines, Northwestern Utilities lance son programme de remplacement de l'ensemble des conduites principales et des branchements en acier nu d'Edmonton. Évalué à 80,9 millions de dollars, ce programme, d'une durée prévue de dix ans, que finance l'organisme précité, vise à remplacer 200 km de conduites principales et 18 300 branchements. Jusqu'à présent, deux ans après le début du programme, 45 km de conduites principales et 3 385 branchements ont effectivement été remplacés. On s'est servi d'une nouvelle technique pour remplacer 23,4 km de conduites principales et 2 166 branchements. Elle consiste à insérer dans les conduites d'acier en place une canalisation en polyéthylène de section inférieure. Pour maintenir la même capacité, on fait passer la pression de fonctionnement du réseau de 1,72 kPa à 100 kPa. Cette technique d'insertion coûte 64 p. 100 moins cher que l'enfouissement direct en raison de la moindre envergure des travaux d'excavation, de remblayage et de remise en place. En raison de la capacité requise, il faut avoir recours à

l'enfouissement direct pour le reste des conduites principales et des branchements, notamment parce que la canalisation en place est trop peu profonde ou que l'emplacement ne s'y prête pas.

INTRODUCTION

Northwestern Utilities' bare-pipe replacement program is a 10-year project to replace all bare-steel mains and services in the City of Edmonton. The program currently costs an estimated $80.9 million and is being funded by Northwestern Utilities Limited. Annual reviews of the program will be conducted to ensure costs are maintained at reasonable levels.

The mains and services included in the program were all installed between 1923 and 1933. They were constructed of bare-steel pipe and could not be effectively protected from corrosion. They provided good service for 60 years, until increasing maintenance costs became significant and were projected to be prohibitive in the near future.

In 1984, a leak study was carried out to identify the problem. The results of the study indicated the bare pipe in the system contributed an inordinate number of leaks to the repair budget. The study also defined the area in question which includes 200 km of main and 18,300 services.

In 1986, a formal replacement program was started. A budget and schedule were established. Replacement techniques were researched to find the most economical method. The insertion method was found to be the best alternative. It uses a small-diameter polyethylene (PE) pipe inserted into the existing steel pipes. To maintain capacity, however, the operating pressure of the system had to be increased. The existing system operated at 1.72 kPa. Further study found that increasing the pressure to 100 kPa can maintain the capacity. Further increases in pressure increased capacity allowing further reductions in pipe size. The problem of water entering the annulus, freezing, expanding, and collapsing the PE pipe, as reported by other companies, was overcome by ensuring that the PE pipe occupies more than 30 percent of the volume of the steel pipe.

In 1987, the first replacements were completed in the Norwood and Downtown areas of Edmonton. Additional replacement work was completed in the Kingsway and the Alberta Municipal Partnership in Local Employment (AMPLE) areas in 1988. Of the mains 52 percent and of the services 64 percent were replaced by insertion, the remainder by direct burial either at the same or a new alignment. Direct burial was required because the existing pipe was too shallow or new capacity requirements exceeded the capacity of inserted PE pipe.

HISTORY

Northwestern Utilities' started serving the City of Edmonton with natural gas in 1923. The gas provided was piped into the city from the Viking Field, 130 km southeast of Edmonton. The gas was delivered to each customer by an uncoated steel pipe. The pipes were joined by mechanical couplings. Most of the work was done by hand. Uncoated pipe was used until 1933. The system operated at low pressure (1.72 kPa). The low-operating pressure required the use of larger diameter (114 mm to 323 mm) pipe.

After 1933, coated pipe was used for mains and services. Natural gas service to the remainder of the City was installed using coated pipe. In 1939, new systems were designed and operated at medium pressure (100 kPa). The higher pressure allowed the use of smaller-diameter pipe than low pressure (42 mm to 219 mm). In 1960, cathodic protection was installed on coated systems to further extend the life of the pipe.

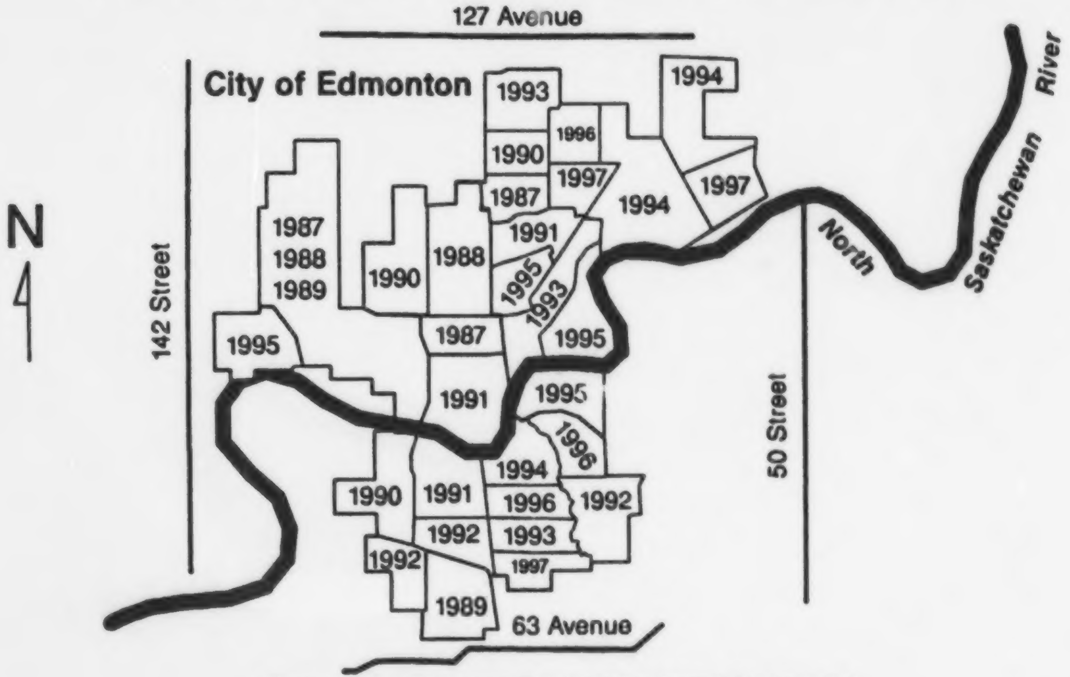
The low-pressure system was operated and maintained for 60 years. Operating and maintenance costs were increasing but did not become significant until the 1980s. In 1984, a study was commissioned to determine the cause and possible solutions to the increasing problem of leaks. The study identified the area serviced by bare pipe (see Figure 1), as the one with an inordinate number of leaks. The following alternatives were recommended for evaluation to deal with the bare-pipe system:

- total replacement of all bare pipe,
- installing a cathodic protection system on the bare pipe, and
- maintaining the status quo.

Given the increasing cost of maintaining the status quo in the bare-pipe system, the other two alternatives were investigated further. The increasing costs of repairing leaks with patches or short replacements increases at an exponential rate (see Figure 2). The cost of total replacement increases linearly. Figure 2 shows that total replacement is the better alternative just 6 years after the work has started.

The environment and the condition of the bare system makes effective installation of cathodic protection impossible for the following reasons:

NORTHWESTERN UTILITIES LIMITED


127 Avenue
City of Edmonton
N
142 Street
50 Street
63 Avenue
North Saskatchewan River
1993
1994
1996
1990
1997
1987
1997
1994
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1995
1987
1995
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1996
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1990
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1996
1992
1992
1993
1992
1997
1989

Figure 1: Bare Pipe Area The Showing Annual Replacement Sequence

NORTHWESTERN UTILITIES LIMITED
Millions of Dollars

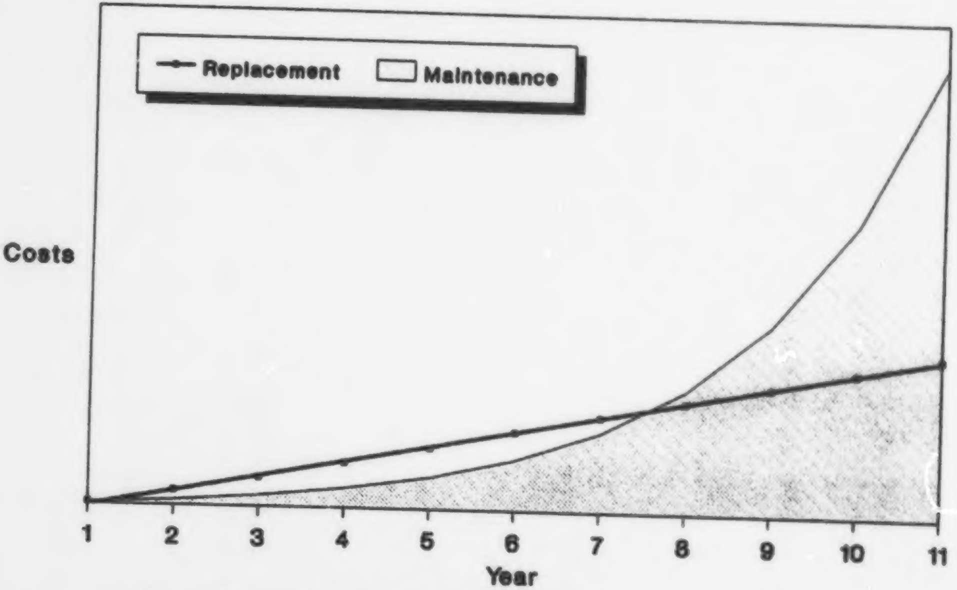

Figure 2: Projected Costs of Maintenance And Replacement In The Bare Pipe Area

1) The mechanical couplings used to join the pipe when it was first installed do not necessarily conduct electricity. All non-conducting couplings would have to be found and the situation remedied.

2) The bare-pipe system is situated in a high-interference area; trolley lines, LRT lines, high-voltage power lines, etc. Power lines induce a current on pipelines that can reverse cathodic protection currents.

3) The soil conditions are not conducive to maintaining a cathodic current on the pipe.

4) A large enough cathodic protection system in the downtown area of the city would be difficult to install and maintain.

For these reasons the total replacement approach was implemented. The replacement included all bare mains and services as well as isolated sections of coated pipe within the bare-pipe area (see Figure 1). Total replacement provides the opportunity to build additional capacity into the system to allow for future growth.

REPLACEMENT PROGRAM

With the decision made to replace the bare system, the area was surveyed to determine the magnitude of the replacement, so that a budget, a replacement sequence, and replacement techniques could be determined. Also, replacement criteria were needed for decision-making and any new replacement techniques needed a procedure.

Magnitude

The bare pipe is situated within a 56-km^2 area in the centre of the City of Edmonton. It includes residential subdivisions, small commercial establishments, and the downtown core. The gas mains are in back lanes, residential streets, collector streets, and major arterial roads. There are 200 km of mains, consisting of 137 km of low-pressure, 44 km of medium-pressure, and 19 km of intermediate-pressure pipes. There are 18,300 services; 13,800 low pressure and 4,500 medium pressure. Some of the original low-pressure system was converted to a medium-pressure system to handle increasing loads.

Budget

On the basis of preliminary estimates from contractors who have done similar work in other cities, experience from other companies, and internal experience from small-scale projects, a budget of $80.9 million was prepared and approved. The budget is divided up for mains, services, meter sets, etc. (see Figure 3). The project will be wholly funded by Northwestern Utilities.

Annual Sequence

The whole replacement cannot be completed in 1 year because of financing, manpower, and scheduling constraints. It will be completed in 10 years, with three or four contracts awarded each year. The area was broken down into 30 roughly equal segments guided by geographical and existing system constraints. The segments were prioritized on a number of leaks and potential consequences basis. The replacement sequence will be reviewed annually to adjust for changes in leak frequency with high-frequency areas taking priority. Figure 1 shows the proposed annual replacement sequence. The 1987 and 1988 segments have been completed.

Replacement Criteria

The replacement criteria refined the overall decision to replace all bare pipe and associated coated pipe. It is used as a decision-making tool when working with individual segments of pipe. The guidelines were based on the following principles:

1) Return trips for further repairs within 5 years is unacceptable for public relations and economic reasons.
2) Isolated sections of steel pipe should be minimized so that cathodic protection can be accomplished effectively and economically. Many small sections are operationally difficult and cumbersome to monitor and maintain.
3) PE pipe is preferred over steel pipe, because PE does not corrode and therefore does not require corrosion protection.

In general, all steel pipe will be replaced if it satisfies any one of the following criteria:

- the pipe is bare steel or has threaded joints;
- non-standard pipe was used; for instance, invasion tubing or PVC;
- the pipe fails a pressure test or has had leaks recorded and repaired;
- the pipe has a suspect coating;

- the pipe has not been cathodically protected for more than 5 years of its service life;
- the pipe has more than three unharnessed mechanical joints per block;
- the present location is unsuitable; for example, shallow cover, future abandonment; and
- the pipe is situated in a high cathodic interference area; for instance, adjacent to a high-voltage power lines.

Replacement Techniques

The majority of the bare pipe was designed for and operated at low pressure. The remainder was intermediate-pressure (550-kPa) pipe which is used to feed district regulating stations or medium-pressure pipe that had been converted from low-pressure pipe. As low-pressure systems use pipe of larger diameter, a new replacement technique could be used. This new technique involves inserting a PE pipe of smaller diameter into the existing steel. By designing and operating the new PE pipe for a higher-pressure system, capacity could be maintained or enhanced. The main advantage of insertion is that considerably less pavement breaking, excavation, backfill, and pavement restoration is required. This reduces costs over trenching by 64 percent and also reduces the time required to complete a section of mains.

Several alternative pressures for the replacement system were evaluated. The higher the pressure used, the smaller the pipe needed to maintain capacity. This would allow some initial cost savings. However, water can enter the annulus between the old steel and the new PE pipes. As the gas pipe is within the freezing zone of the soil, any water in the annulus will freeze. If a sufficient volume of water is present, the expansion due to freezing will collapse the PE pipe. This phenomenon will increase long-term operating and maintenance costs, thus outweighing the initial cost savings of smaller pipe. Water expands by roughly 10 percent when it freezes. Therefore, to prevent the PE pipe from collapsing, it must occupy more than 10 percent of the volume of the steel pipe. However, a partial collapse of the pipe will restrict the capacity of the pipe. To avoid the restriction, a lower limit of 30 percent of the volume of the steel pipe has been specified. Medium pressure satisfied both conditions; the pipe would be small enough to insert, yet it would occupy sufficient volume in the steel pipe that freezing water would not collapse it. In general, medium-pressure pipe, which is two sizes smaller, will have the same capacity as low-pressure pipe.

NORTHWESTERN UTILITIES LIMITED

Mains Replacement	$33,945,000
Service Replacement	17,221,000
Meter Set Replacement	10,116,000
Station Improvements	2,000,000
Sub-total	$63,282,000
Mains Removal	11,272,000
Service Removal	5,936,000
Meter Set Removal	366,000
Station Removal	82,000
Sub-total	17,656,000
Total	$80,938,000

Figure 3: Bare Pipe Replacement Program Current Estimates By Account

Another problem that had to be addressed was that of damage to the PE during insertion. PE being a softer material than steel can be easily scratched. Current natural-gas codes allow a maximum depth scratch or gouge of 10 percent of the wall thickness. This could be easily exceeded given the nature of the installation and repairs of the existing steel pipe. The pipes were originally joined with mechanical couplings. The couplings do not align the pipes perfectly. The pipe end of the misaligned pipe could cause gouges or scratches. The oxy-acetylene process used to weld joints leaves sharp protrusions in the pipe which will cause scratches. Service tees were installed by chiselling a circular indentation into the pipe wall, welding on the tee, and then knocking out the indentation with a hammer. The indentation or coupon was left in the pipe. It may be still attached to the pipe and its sharp edges could cause scratches or gauges. Some pin hole leaks were repaired by driving a nail or screw through the hole and welding it in place. The nail could cause scratches. These problems are overcome by also inserting a thin wall PE pipe, called a sleeve, into the steel pipe prior to inserting the PE gas carrier pipe. The sleeve protects the carrier pipe by keeping it away from the source of potential damage. The sleeve is left in place to absorb any future damage caused by relative movement between the carrier pipe and the steel pipe. The sleeve adds some cost to the replacement, but not enough to make direct burial or trenching economically more attractive.

If for various reasons insertion cannot be used, the steel pipe is replaced by relocating the new pipe or by placing the new pipe adjacent to the existing one by direct burial. The reasons include:

- insufficient capacity in the inserted size due to system design or load changes;
- the existing steel pipe is too shallow;
- abrupt changes of direction or protrusions that occupy too much of the pipe volume; and
- the existing pipe is in an unsuitable location; for instance, on the same alignment of other deeper utilities.

RESULTS/PROGRESS

At the end of 1988, 2 years of construction have been completed; in that time three of 30 areas have been completed. In a fourth area, the AMPLE area where Northwestern Utilities is coordinating gas pipe replacement with the City of Edmonton's sewer and water replacement, the gas pipe replacement is 57 percent complete. The AMPLE segment is roughly equal to four normal areas. This amounts to five completed areas in total, keeping the project on target for completion in 10 years.

In the 2 years of construction, 45 km of main have been replaced, 23.4 km by insertion and 21.6 km by direct burial. 3,385 services have been completed; 2,166 by insertion and 1,219 by direct burial. Insertion was used for 52 percent of the mains and for 64 percent of the services. The insertion percentages are expected to increase. In 1988, more direct burial was done because of capacity requirements, the existing steel pipe was too small for inserting a PE pipe, steel pipe was used, and direct burial was used where gas pipe replacement was coordinated with the sewer and water replacements. The percentage of insertion for mains and services is expected to rise to roughly 55 percent for mains and 70 percent for services as more of the older areas with the larger low-pressure pipe are completed.

In the AMPLE area, the Inglewood, Oliver, and Westmount communities, the City of Edmonton and Northwestern Utilities are coordinating the sewer, water, and gas replacements. The construction steps used are here briefly described:

1) The City's contractor removes asphalt.

2) Northwestern Utilities' contractor installs a temporary gas main on the side of the lane out of the way. The existing services are connected to the temporary main. The existing steel main is disconnected at both ends and purged of gas.

3) The City's contractor replaces the sewer and water mains. The existing gas main is also removed at this time to make work easier for the sewer and water replacements. The lane is backfilled and compacted.

4) Northwestern Utilities' contractor installs the new gas main and replaces the services. The gas main trench and service bellholes are backfilled and compacted.

5) The City's contractor completes surface restoration.

This process reduces the impact on the residents of the area. All of the replacement work is completed in one session, instead of two or more, to which the residents would object. The duration of the construction is longer than that required for only one of the replacements, but shorter than for all three, if they were to take place at different times because all the excavation and restoration must be redone each time. The use of the temporary gas main removes the obstruction and hazard of having the sewer and water contractor work around a live gas main. In some cases the gas main would have to be supported while the sewer and water mains were replaced underneath it.

1988 was the first year the City and Northwestern Utilities coordinated their respective replacements. There were some coordination problems that had to be worked out. Neither contractor completed activities as quickly as hoped which caused delays to the other contractor. These delays had a snowballing effect; however, all the planned gas mains and services were replaced, except for one block and some clean up, which will be completed in 1989. All of the replacements planned by the City were completed, except two blocks of sewer and water mains; these will also be completed in 1989. The 1989 phase of the AMPLE replacements will be more closely controlled and coordinated, so that the delays similar to those which occurred in 1988 can be avoided. With better estimates of time requirements, the experience gained, and closer cooperation, the replacement project should run more smoothly in 1989.

CONCLUSION

Northwestern Utilities' bare-pipe replacement program is a 10-year project aimed at replacing all mains and services installed in the City of Edmonton between 1923 and 1933. Also replaced will be some of the younger, coated mains and services in adjacent areas whose life has been affected by being electrically connected to the bare-steel pipe. (Coated pipe acts as a sacrificial anode to bare pipe.) The bare-steel system provided good service for 60 years until increasing leaks gave rise to prohibitive repair costs.

To the end of 1988, Northwestern Utilities has replaced 45 km of 200 km of bare-steel mains and 3,385 of 18,300 bare-steel services. $13.7 million of the $80.9 million budget has been spent. The remainder of the bare-steel mains and services will be replaced in the next 8 years. The insertion replacement technique has been used to replace 52 percent of the mains and 64 percent of the services. The remainder was installed by direct burial. The percentage for mains and services is anticipate to increase to 55 and 70 percent respectively as more of the larger pipe is replaced.

The budget, annual sequence, and criteria and procedures [illegible] replacement techniques have been developed. They will be reviewed annually to ensure costs and procedures are maintained at reasonable levels.

Further replacements will be coordinated with other utilities where the replacement projects overlap. This will reduce the impact of construction on the residents and businesses in the area.

THE INSITUFORM METHOD OF TRENCHLESS PIPE REPLACEMENT

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ABSTRACT

The growing need for the rehabilitation of Canada's aging sewers and watermains will require the use of renovation techniques, rather than conventional open-cut excavation, in many instances to minimize disruption and provide a cost-effective solution.

This paper reviews the Insituform® process which was developed in England in the early 1970s and is now used throughout the world as a cost-effective alternative to expensive pipe replacement. Information is provided covering the following areas:

- manufacturing and installation process
- applications for Insituform
- design considerations
- reduction in construction time and community and business disruption
- ongoing development of new technology
- life expectancy of Insituform

RÉSUMÉ

Le vieillissement des réseaux d'égouts et de conduites maîtresses d'alimentation en eau au Canada fait ressortir le besoin croissant de procéder à leur réfection, mais en faisant appel à des techniques de rénovation plutôt qu'aux méthodes d'excavation

habituelles, pour réduire le plus possible les interruptions de service et offrir une solution efficiente.

L'exposé brosse un tableau de la technique Insituform, mise au point en Angleterre au début des années 1970 et adoptée dans le monde entier comme solution efficiente au remplacement coûteux des canalisations. Les renseignements fournis concernent les aspects suivants :

- la fabrication et l'installation;
- les applications se prêtant à cette technique;
- la conception;
- la diminution de la durée des travaux et des interruptions de service autant pour la collectivité que pour les entreprises commerciales;
- le développement constant de nouvelles technologies;
- la durée utile d'Insituform.

INTRODUCTION

The Insituform process, developed by Eric Wood in 1971, was first used commercially in the United Kingdom in 1973 and has now become the premier pipe and sewer reconstruction system in the world.

Developed to overcome the problems of failed or failing pipes, be they sewers or industrial pipework, underground or just inaccessible, Insituform provides a new structural pipe within the original pipe, greatly extending its life.

Since its first commercial use in 1973, Insituform has been used successfully in 40 countries with over 2,000 km having been renovated by this process.

Applications vary widely in terms of size, depths, lengths of runs, pressures and types of effluents handled. It has been used to renovate circular pipes from 75 mm up to 2,700 mm in diameter with wall thicknesses ranging between 3 mm to 50 mm. Insituform is also often used to renovate egg-shaped sewers with the largest being a 2,400-mm oval pipe in St. Louis, Missouri. Box sections, flat tops, and manhole chambers have all been successfully renovated with this process.

MANUFACTURING AND INSTALLATION PROCESS

The Insituform method appears to be very simple. The length of pipe to be reconstructed is surveyed by CCTV camera or visually, whatever means is appropriate.

Based on this condition survey and other information obtained from the client, a design for the Insituform will be undertaken which will take into account the structural condition of the existing pipe, infiltration problems, type and content of effluent, ground and loading conditions, and groundwater table level.

The length of pipe to be constructed is cleaned of all loose debris and heavy scale with any protruding lateral connections being reamed out so that they will not impede the inversion process. Where a sewer or pipe carries a flow, the flow through the section will be overpumped.

A tube (Insitutube®) is manufactured of polyester felt exactly equal to the internal circumference of the pipe to be renovated. The outer layer is coated with a polyurethane membrane. Resin is then mixed with a catalyst and pumped into the felt liner totally impregnating it. The Insitutube is then taken to the site and turned inside out into the defective pipe in a process known as inversion.

Normally the Insitutube is inserted from an existing manhole so that no excavation and hence no disturbance to surface features, such as roads, trees, fences and buildings or underground utilities which are often close to the sewer, is required.

Cold water pressure forces the Insitutube through the pipe, inverting and pressing it firmly against the pipe wall. Once it is in place, hot water is circulated through the pipe causing the thermosetting resin to cure into a hard, structurally sound "pipe within a pipe".

The formation of the Insitupipe will block any lateral connections; however, at these connections the Insitutube forms a concave dimple indicating its location. In man-entry sewers, the connection will be re-opened using a hand-held cutter, whereas in other pipes, remote controlled cutters are used.

APPLICATIONS

The Insituform process was developed to provide a means of rehabilitating existing pipes without excavation. Some typical applications include:

- strengthening existing structurally deteriorating pipes,
- eliminating infiltration of ground water in gravity pipelines,
- reducing maintenance by eliminating root intrusion and deposition of solids,
- internal corrosion protection of pipelines,
- prevention of exfiltration of pipeline contents,
- increasing the flow capacity of existing pipelines by smoothing the interior surface, and
- elimination of leaks in pressure pipes.

These applications include both circular and non-circular pipes, square culverts, and corrugated metal pipes.

DESIGN CONSIDERATIONS

The Insituform process is extremely flexible since the materials used can be selected to suit a wide variety of environments. The felt tube is used only as a carrier to place and retain the polymeric material. Three types of polymeric material are available for use in the process, depending on the type of environment to be encountered. Polyester resins are normally used for municipal sewers, epoxy resins where greater strength is required and where pipes carry potable water, and vinyl ester resins where greater corrosive and abrasive resistance is required.

The structural design life for Insituform is based on a minimum of 50 years calculated in accordance with the Water Research Centre (UK) requirements. The factors which must be considered when specifying an Insitutube for a particular application include the following:

- diameter (or perimeter) of the pipe,

- length of continuous run of the pipe for each installation,
- structural condition of the pipe,
- pressure or non-pressure pipe,
- depth of pipe,
- height of water table, and
- type of effluent.

This information is necessary because the Insitutube is custom-made for the problem it is to overcome. Based on the information received for each project, a detailed design process is followed to determine the thickness of the tube and the type of resin required.

In July 1988, an independent test was conducted at Utah State University to determine the structural support that can be provided to a failing rigid-pipe system through the use of the Insituform process. The test was designed to determine the composite ring strength of the concrete/Insitupipe system.

The test was conducted by placing two parallel sections of pipe in a large soil cell. The pipes in both test sections had been broken under controlled conditions, prior to burial, and some section had been repaired using the Insituform process. Vertical soil load was applied by 50 hydraulic cylinders attached to 10 reaction beams. Vertical and horizontal diameters of both test sections were measured after each increment of load.

A preliminary vertical soil pressure of 10,000 kPa (equivalent to 3.6 m of soil) was applied with a corresponding pipe deflection of 2 percent in each section. One of the pipes was then Insituformed with a 21-mm thick tube designed to withstand a burial load equivalent to 9.1 m of soil.

Vertical loads were then applied in increments of 5,014 kPa by the hydraulic cylinders. After each increment of load, the vertical and horizontal deflections were measured. The procedure was continued up to a soil load of 60,166 kPa (equivalent to 22.2 m of soil cover). Table 1 summarizes the results of the test program.

Table 1
Results of Test for Composite Ring Strength

		Percent Deflection	
Load (kPa)	Equivalent Depth (m)	Rigid Pipe	Insituformed Pipe
15,041	5.55	0.2	0
20,055	7.38	3.0	0
25,069	9.24	5.2	1.7
30,083	11.09	7.7	3.3
35,097	12.92	10.2	5.0
40,110	14.78	12.7	6.7
45,124	16.61	15.2	8.3
50,138	18.47	17.7	10.0
60,166	22.16	21.0	13.2

As indicated in Table 1, the deflection of the Insituformed pipe did not commence until a load equivalent of 7.4 m of soil was reached and its deflection was substantially less than that of the unrepaired pipe throughout the tests.

At the final loading (equivalent to 22.2 m of soil cover), the Insituformed pipe did not break and was fully functional, whereas the unrepaired pipe was unserviceable and would have collapsed if flow had been in the pipe. This independent test proved conclusively that Insituform adds significant strength to buried, broken pipe while retaining service capability.

It is important to note that in an actual installation, vertical pressure rarely increases. Underground pipes collapse as a result of losing sidefill support by erosion. Therefore, the fact that an Insitupipe stops leaks may be even more important than the fact that it increases the strength of the old pipe.

A second test was undertaken by using two Insitutubes, 750 mm in diameter, without encasement. One Insitutube had a 21-mm thick wall impregnated with a standard resin; and the second, a 16.5-mm thick wall impregnated with an enhanced resin. A methodology similar to that of the first test was used. Table 2 summarizes the results of the test program.

Table 2

Results of Strength Tests

		Percent Deflection	
Load (kPa)	Equivalent Depth (m)	Standard Resin (21-mm wall)	Enhanced Resin (16.5-mm wall)
20,690	7.62	3.8	5.0
23,193	8.53	5.0	5.9
41,379	15.24	10.1	12.5
50,345	18.53	12.1	15.4

The Insitupipes neither collapsed nor cracked, even at 7,300 psf of pressure (equivalent to 18.5 m of fill). This test proved that even without encasement an Insitupipe has enough structural strength to support heavy loads.

An aspect often overlooked in the design process is the increase in capacity that occurs after a pipe has been restructured with Insituform. The much smoother surface of the new pipe, together with the smooth transitions at offsets and protrusions and the elimination of joints, results in increases of flow velocity, often significantly. The smooth surface also improves capacity by reducing deposition. The continuous nature of the new pipe within the old keeps debris moving, increasing flow and reducing maintenance. The Insitutube roughness value used in the Manning equation is 0.009, and in the Colebrook-White equation, the equivalent value is 0.6 mm.

SOCIAL AND BUSINESS DISRUPTION

Normally when a renovation project is being proposed, the evaluation of the alternatives is based on the actual construction cost of the project. Little, if any, consideration is given to the costs related to social and business disruption.

A major advantage of the Insituform process is that it is normally a complete "no-dig" solution, and as such it dramatically reduces the impact on traffic and neighbouring residences and businesses.

On a normal project the length of one city block, say, 150 to 200 m, the Insituform inversion, curing, and re-opening of services would take approximately 24 hours with all access to the sewer being provided by way of existing manholes. If the sewer is located in a street then approximately one lane of traffic will be occupied by the Insituform equipment, thus still allowing traffic the use of the street. When compared to the length of time taken by conventional open-cut techniques for a similar job, the reduction in time, disruption, and inconvenience is dramatic.

We believe that when a municipality is evaluating alternative methods for undertaking a renovation project, this factor should be one of the major considerations.

NEW TECHNOLOGY

Technical centres have been founded in Wellingborough, England, and Memphis, USA, to undertake development work to expand and upgrade the technology offered. Currently, three new systems are entering the commercial market and will have an impact on the renovation market for urban infrastructures. These are light-cure, potable water systems and lateral linings.

The light-cure system is an interesting alternative to the traditional heat-cure system. Curing of the polymer is achieved by passing a string of ultra-violet lights through the tube after inversion to effect rapid and consistent curing of the resin. The equipment for this system is smaller, less expensive, and more versatile. This system will have particular advantage for long inversions, submarine work, or work at high ambient temperatures where conditions impose tough demands on heat-curing apparatus. Where mains electricity is available, the curing process is almost silent and the environmental nuisance is minimal. Light cure is over 50 percent faster than heat cure in many situations. It is anticipated that this system will be available in Canada later in 1989 or early in 1990.

Following years of stringent testing by national authorities in different parts of the world, the Insituform process is beginning to receive approval for use in potable water pipelines. Japan was the first country to approve the process, followed by Norway; and more recently, conditional approval was received in the USA. Detailed tests carried out in the United Kingdom have passed the materials as suitable for use in potable water pipelines and final approval is being sought. To meet the requirements for potable water, the system will use Insitutubes with a surlyn nylon coating and epoxy resins. The application to gain approval in Canada will commence soon and will be based on the detailed testing undertaken in the USA and Europe.

A technique has been developed to permit the lining of laterals from within the main in both man-entry and other (smaller) sewers. This process will allow a complete Insituform structure to be installed without excavation. This lining system is currently under final field-testing and will be available to licencees shortly.

Other research is ongoing into improved materials and resins especially with respect to reinforced Insitutubes and improvements in the physical properties of resins.

LONGEVITY

A question often asked is, "How long will Insituform last?" With nearly 20 years of successful installations, there is now a wealth of positive data available to show that Insituform is likely to be at least as long-lasting as any other material in comparable environments.

The very first installation was undertaken in a 1,175- by 610-mm, egg-shaped pipe in London in 1970, while still in its experimental stage. In 1984, the Thames Water Authority removed samples from the pipe for testing. Despite an aggressive environment, caused by hot caustic waste and abrasive solids, the Insitupipe was found to be in excellent condition.

Another early installation, constructed in 1972, comprised three 2,450-mm circular pipes at a pumping station in London's East End. In 1982, the Thames Water Authority carried out detailed inspections and testing, and determined that the pipes were in "first class-condition, with no sign of wear or deformation". As a result of this inspection, the Authority declared no further testing would be undertaken for another 10 years.

These and many other installations have proven that Insituform will last for many years. With the introduction of new unproven techniques, which are likely in the next few years, this long product history is important to understand.

SEWER RENEWAL/REHABILITATION IN CALGARY, ALBERTA

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ABSTRACT

The key activity to maintenance and renewal/rehabilitation programs in the City of Calgary is the use of TV video records. TV inspections identify the degree of deterioration of the utility for our decision-making process to renew or rehabilitate. Most renewal is restricted to older clay pipe and to where corrosive soils are acting on concrete pipe. The majority of replacement/rehabilitation has occurred in areas of the city that exceed 20 years in age. Approximately 80 percent of the present sewerage was installed in a 30-year residential expansion period between 1951 to 1981. Consequently, the majority of the system is about the same age and is reaching a median age of 20 years. Structural deterioration is taking place; the potential for a large percentage of the system to require renewal/rehabilitation in the future is significant. The Sewer Division of the City's Engineering Department is in the preliminary phase of developing modern techniques of maintenance and renewal/ rehabilitation for the sewer infrastructure.

RÉSUMÉ

La clé du programme d'entretien et de renouvellement ou de réfection de la Ville de Calgary réside dans des enregistrements d'inspection sur bande vidéo. En effet, ces inspections permettent d'établir le degré de détérioration des services d'utilité publique et

ainsi de former la décision de renouveler le réseau ou d'en effectuer la réfection. Les travaux de remplacement se limitent en majeure partie aux anciennes canalisations d'argile et aux endroits où le sol corrosif attaquent les conduites de béton. La majorité des travaux de remplacement ou de réfection ont touché des secteurs de la ville datant de plus de 20 ans. Le réseau d'égouts actuel a été installé, dans une proportion d'environ 80 p. 100, lors de la période d'expansion des quartiers résidentiels survenue entre 1951 et 1981. L'âge du réseau est donc sensiblement la même partout, soit en moyenne 20 ans. La détérioration structurale commence à se manifester, de sorte qu'un fort pourcentage des conduites du réseau devra être renouvelé ou remis en état. La division des égouts du génie municipal a déjà entrepris la première étape de la mise au point de techniques modernes d'entretien et de renouvellement ou de réfection des conduites d'eaux usées.

INTRODUCTION

Throughout Europe and North America, there have been a number of growing concerns for the ability of the present utilities to fulfill the demands of the future. The Engineering Department in the City of Calgary shares many of these concerns for our infrastructure. Demands on the existing systems may be significantly different from the original design conditions. Because of the continual aging of these utilities coupled with the spiralling upgrading and replacement costs, a new trend to economize and a political interest to minimize tax increases have placed a greater emphasis on developing effective maintenance programs and finding methods to prolong the utility life beyond original expectations.

Calgary underwent accelerated rates of expansion from 1951 to 1981. Our operation was more in tune with the development and inspection of the new system while less emphasis was given to infrastructure maintenance. Over the last 5 years, we have been taking a serious look at our maintenance programs.

The key element in our long-term strategy is the development of a sewer maintenance and renewal/rehabilitation planning system.

Existing Sewer Infrastructure

According to City records, sewer installation started in Calgary in 1890. Calgary's sewers are based on a separated sewer system. The Sewer Division presently operates 2600 km of sanitary and 2100 km of storm sewer. As illustrated by Figure 1, two significant periods of population expansion occurred: from 1904 to 1914 and from 1950 to

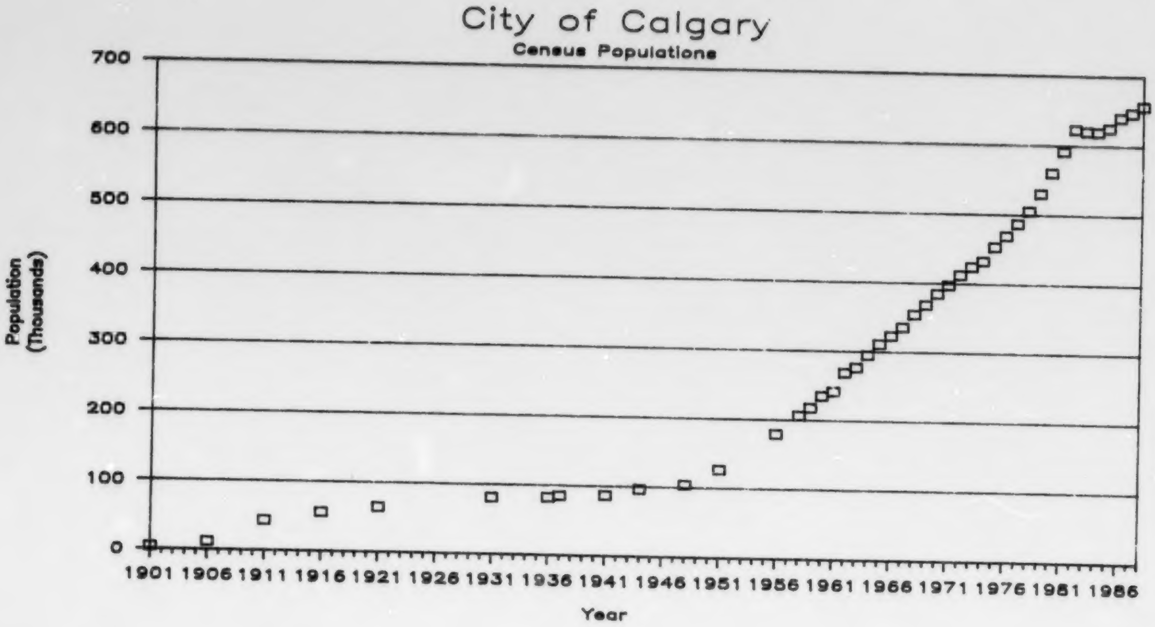

City of Calgary
Census Populations
Population (Thousands)
700
600
500
400
300
200
100
0
1901
1906
1911
1916
1921
1926
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
Year

FIGURE 1

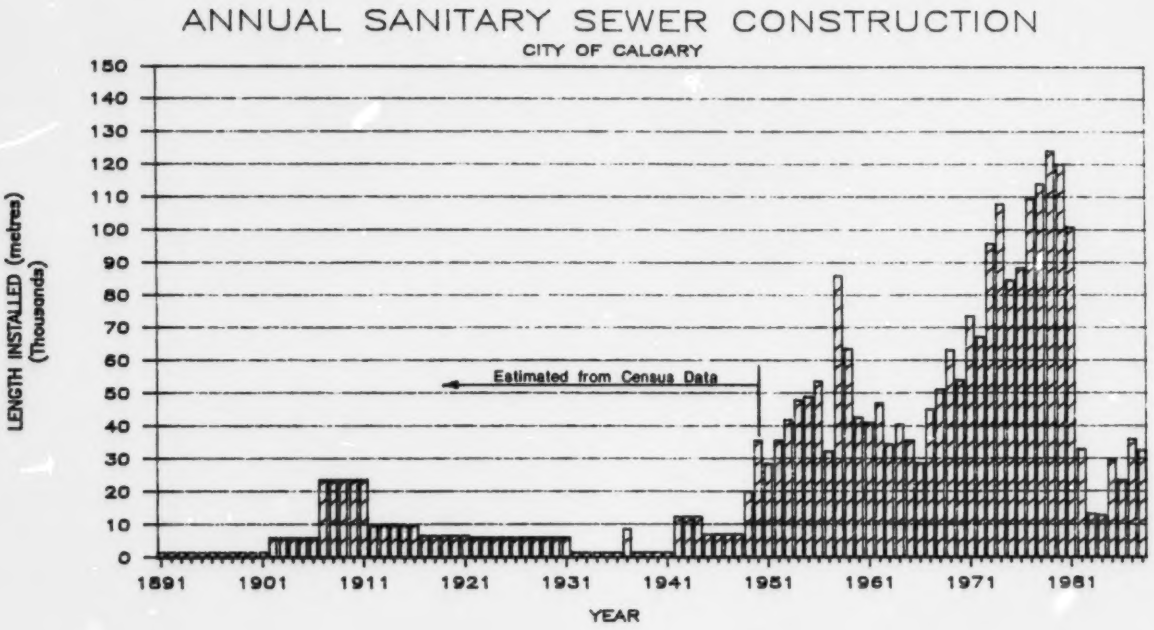

ANNUAL SANITARY SEWER CONSTRUCTION
CITY OF CALGARY
LENGTH INSTALLED (metres)
(Thousands)
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
Estimated from Census Data
1891
1901
1911
1921
1931
1941
1951
1961
1971
1981
YEAR

FIGURE 2

1981. Theses high-growth period correspond to periods of major infrastructure expansion for the city. Figure 2 shows the trends of the high growth on the utilities after 1950 and the recessionary effect in 1981.

The use of polyvinyl chloride (PVC) pipe in diameters of less than 375 mm has only recently begun for sanitary sewer; previously the predominant use had been concrete. Concrete is used exclusively in our storm sewer installations. We have the following inventory of major infrastructure components as of December 1988.

Sanitary Sewer Pipe	2,667 km
Sanitary Sewer Service Connections	181,515
Sanitary Sewer Manholes	31,610
Storm Sewer Pipe	2,109 km
Storm Sewer Manholes	26,697
Catch Basins	36,405
Storm Sewer Outfalls	428

Infrastructure management can be divided into four general categories, which are flexible and tend to interact with and augment each other:

- information gathering/databases
- preventive maintenance
- renewal/reconditioning
- monitor performance

In 1978, the City took the first step toward computerized utilities mapping and inventory management.

INFORMATION GATHERING/DATABASES

The foundation to infrastructure management is the source and reliability of system databases. We are proud to have established a comprehensive manual central record system which catalogs all City and private utilities in one central filing system.

To assess the physical makeup and condition of the infrastructure effectively requires accurate information. Consistent and accurate record-keeping is vital in crisis decision-making. Record-keeping includes the physical inventory of the infrastructure; size, length, type, and class of pipe; soil type; bedding material; manholes; depths to invert; date of installation; the number of repairs; service lead and main cleaning frequency; the occurrence of inspections; and complaints and backups. All are examples of useful information that will allow municipal engineers to evaluate infrastructure conditions.

Interactive Graphics

In 1978, the City purchased an interactive graphics system for the purpose of compiling legal base maps for the entire city. Precise base plans are computer-based on which all block and lot corners are coordinated through measured ties to the Provincial Control Survey network. The result is 1,237 maps produced at a scale of 1:1000 and of 1:4000, each covering a 600- by 800-m sector of the city. Versatility of the system allows map merging and gives the ability to create various map products at any desired scale. Presently the locations of all structures, street and traffic lights, curbs, gutters, catch basins, manholes, and trees in downtown Calgary are being entered into the system.

Joint Utility Mapping Project (JUMP)

The JUMP program will be the foundation for inventory database of the overall City infrastructure . The interactive graphics system and software will electronically capture all the utility drawing information in the central records system. This program involves computerizing the as-constructed drawings of all existing facilities within the public rights-of-way, including all City and private utilities.

Sewer and Water Inventory Management System (SWIMS)

With present-day interest in utilizing computers, a program to predict system failures would be a powerful tool for any municipality to manage infrastructure renewal/reconditioning.

In late 1986, the Sewer and Water Inventory Management System (SWIMS) program was initiated to compile the inventory and computerize a database management system by filing important water and sewer system components. SWIMS consists of 12 computer software packages, including service locator, service card data capture, auxiliary drawing system, service inventory finalization, complaint and damage claims.

Our 180,000 service connection inventory has been loaded as a computerized database. We now have digitized connection records for water, and sanitary and storm sewers. The database is connected to the Utility Customer Information System (UCIS) and Address Legal Cross Reference (ALIX). We are now adding the Time Related Event History module to help us along our way to prediction modelling.

Figures 3 through 5 are examples of SWIMS output. Figure 6 illustrates the initial step and the basic information for residential/industrial and commercial utility services. SWIMS is being used daily by senior maintenance personnel. We are currently designing the input to Service Historical Events. The Sewer Division has approximately 10,000 service history cards and is determining how far back we want to digitize our historical events. Anticipated completion of this latest module is during the summer of 1989. Once this second SWIMS module has been input, we will have a powerful tool for preventive maintenance and renewal/rehabilitation programs.

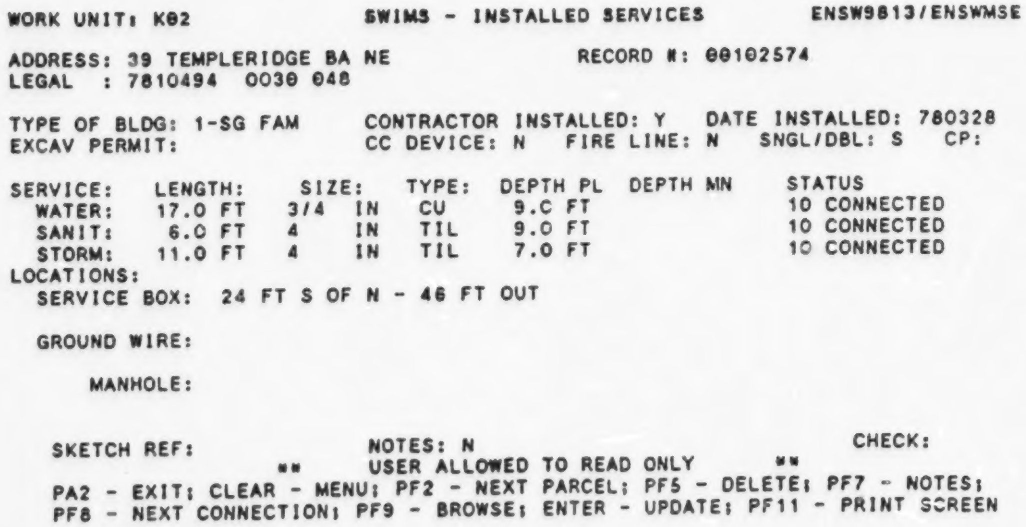
With the progression of SWIMS modules we will be improving our status to the early stages of predictive analysis. Several years of verification will be required before we can definitely establish a good predictive model.

PREVENTIVE MAINTENANCE

Preventive maintenance is the scheduled and sequential performance of maintenance tasks, so that the infrastructure system operates effectively throughout its maximum practical life. Preventive maintenance tasks are usually more service-oriented. Examples are the cleaning and flushing of sewers, inspection and operation of valves and hydrants in the case of watermains, and minor repair of streets, such as crack filling and hot patching, may also be considered preventive maintenance.

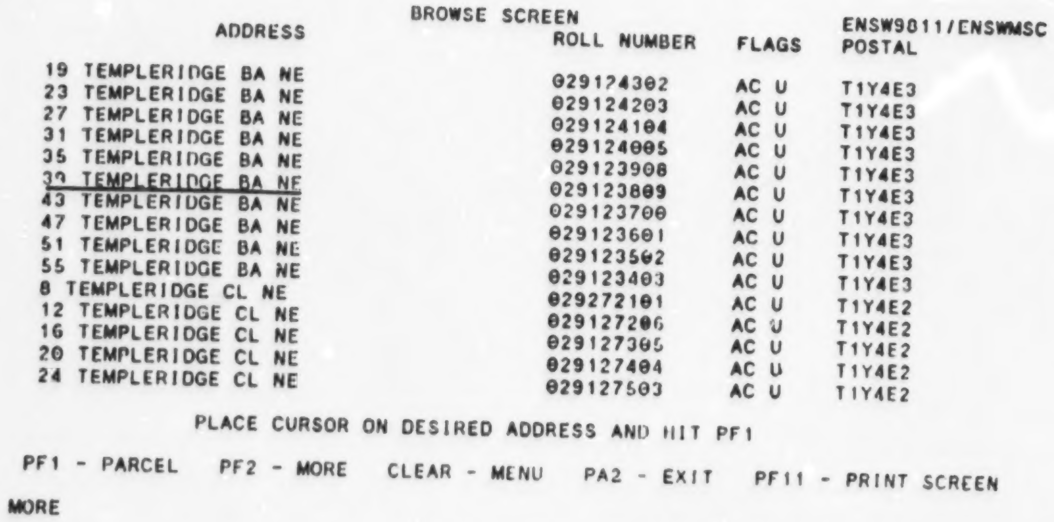
The benefits to developing a sound preventative maintenance program are:

- extension of the service life of existing piping and delay of the need for new costly capital improvements by conventional replacement;



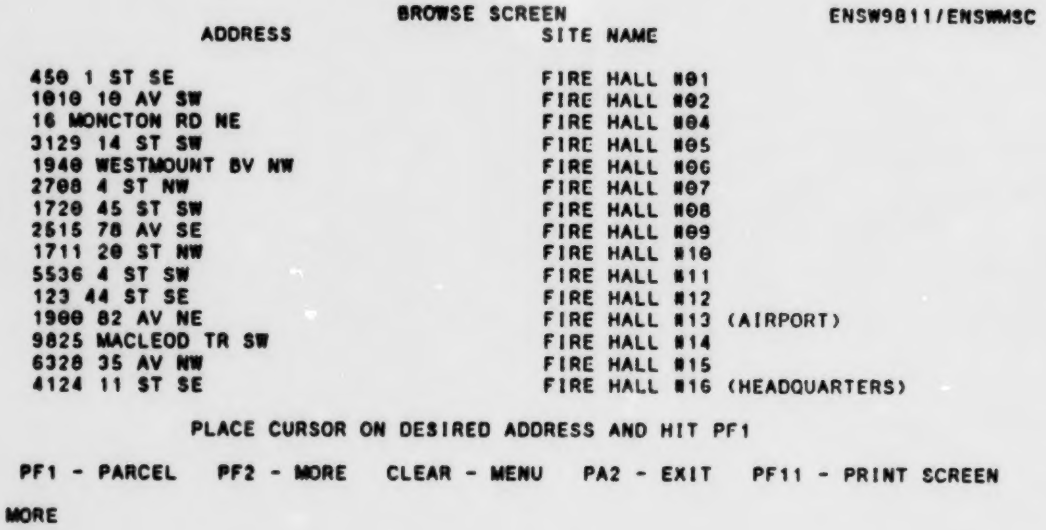
```
WORK UNIT: K02          SWIMS - INSTALLED SERVICES        ENSW9813/ENSWMSE

ADDRESS: 39 TEMPLERIDGE BA NE                 RECORD #: 00102574
LEGAL  : 7810494  0030 048

TYPE OF BLDG: 1-SG FAM     CONTRACTOR INSTALLED: Y  DATE INSTALLED: 780328
EXCAV PERMIT:              CC DEVICE: N   FIRE LINE: N   SNGL/DBL: S   CP:

SERVICE:   LENGTH:    SIZE:   TYPE:  DEPTH PL  DEPTH MN    STATUS
  WATER:   17.0 FT   3/4  IN   CU     9.C FT               10 CONNECTED
  SANIT:    6.0 FT   4    IN   TIL    9.0 FT               10 CONNECTED
  STORM:   11.0 FT   4    IN   TIL    7.0 FT               10 CONNECTED
LOCATIONS:
  SERVICE BOX:  24 FT S OF N - 46 FT OUT

  GROUND WIRE:

      MANHOLE:


   SKETCH REF:            NOTES: N                          CHECK:
               **         USER ALLOWED TO READ ONLY      **
   PA2 - EXIT; CLEAR - MENU; PF2 - NEXT PARCEL; PF5 - DELETE; PF7 - NOTES;
   PF8 - NEXT CONNECTION; PF9 - BROWSE; ENTER - UPDATE; PF11 - PRINT SCREEN
```

FIGURE 3



```
                          BROWSE SCREEN                             ENSW9011/ENSWMSC
                ADDRESS                   ROLL NUMBER     FLAGS     POSTAL

      19 TEMPLERIDGE BA NE                029124302       AC U      T1Y4E3
      23 TEMPLERIDGE BA NE                029124203       AC U      T1Y4E3
      27 TEMPLERIDGE BA NE                029124104       AC U      T1Y4E3
      31 TEMPLERIDGE BA NE                029124005       AC U      T1Y4E3
      35 TEMPLERIDGE BA NE                029123908       AC U      T1Y4E3
      39 TEMPLERIDGE BA NE                029123809       AC U      T1Y4E3
      43 TEMPLERIDGE BA NE                029123700       AC U      T1Y4E3
      47 TEMPLERIDGE BA NE                029123601       AC U      T1Y4E3
      51 TEMPLERIDGE BA NE                029123502       AC U      T1Y4E3
      55 TEMPLERIDGE BA NE                029123403       AC U      T1Y4E3
      8 TEMPLERIDGE CL NE                 029272101       AC U      T1Y4E2
      12 TEMPLERIDGE CL NE                029127206       AC U      T1Y4E2
      16 TEMPLERIDGE CL NE                029127305       AC U      T1Y4E2
      20 TEMPLERIDGE CL NE                029127404       AC U      T1Y4E2
      24 TEMPLERIDGE CL NE                029127503       AC U      T1Y4E2

              PLACE CURSOR ON DESIRED ADDRESS AND HIT PF1

  PF1 - PARCEL   PF2 - MORE   CLEAR - MENU   PA2 - EXIT   PF11 - PRINT SCREEN

MORE
```

FIGURE 4



```
                            BROWSE SCREEN                     ENSW9811/ENSWMSC
          ADDRESS                          SITE NAME

    450 1 ST SE                            FIRE HALL #01
    1010 10 AV SW                          FIRE HALL #02
    16 MONCTON RD NE                       FIRE HALL #04
    3129 14 ST SW                          FIRE HALL #05
    1940 WESTMOUNT BV NW                   FIRE HALL #06
    2708 4 ST NW                           FIRE HALL #07
    1720 45 ST SW                          FIRE HALL #08
    2515 78 AV SE                          FIRE HALL #09
    1711 20 ST NW                          FIRE HALL #10
    5536 4 ST SW                           FIRE HALL #11
    123 44 ST SE                           FIRE HALL #12
    1900 82 AV NE                          FIRE HALL #13 (AIRPORT)
    9825 MACLEOD TR SW                     FIRE HALL #14
    6328 35 AV NW                          FIRE HALL #15
    4124 11 ST SE                          FIRE HALL #16 (HEADQUARTERS)

              PLACE CURSOR ON DESIRED ADDRESS AND HIT PF1

   PF1 - PARCEL   PF2 - MORE   CLEAR - MENU   PA2 - EXIT   PF11 - PRINT SCREEN

  MORE
```

FIGURE 5

- prevention of catastrophic failures and limiting of immediate unplanned expenditures. (Preventive rather than reactive maintenance avoids repairs performed under a time and material crisis and allows competitive bidding.);
- repairs can be performed at a cost-effective time, i.e., coordinated with other street surface improvements;
- performance of repairs before major sewer backups occur, eliminating damage to local property and the overflow of untreated wastewater into streams and rivers;
- overtime pay and related maintenance expenses associated with emergency repairs are minimized; and
- disruption to traffic flow and nuisance to the residents of the City of Calgary are minimized.

We have five defined preventive maintenance activities: TV video inspection, flushing and cleaning, chemical foam control of root penetration, repairs, and infiltration/ inflow control.

Table 1 provides an excellent summary of the activities and their functions.

The cornerstone to the preventive maintenance program is the use of TV video inspection. We have two 63-mm TV cameras to inspect service leads and an 80-mm TV camera to inspect sewer mains. Over the last several years, our main inspection program has responded to demands of the waterworks and streets renewal/rehabilitation programs. Recently we have concentrated our effort on inspecting older areas of the infrastructure. In 1988 and 1989, we are relying more on private contractors to complete a video inspection which covers approximately 1 km^2. Approximately 30 percent of the older areas have been inspected since the start of the TV program.

Currently, video contractors are expected to provide summaries to our standard documentation for easy use by our video personnel. Inspection review is an extensively labor-related task and requires considerable time and effort for review and cataloging. All video inspections are recorded, by tracking the completed mains, on our 1:400 section books. Figure 6 shows an example and the amount of coverage for the sanitary sewer mains in the Marlborough area. Marlborough is known to have high-alkali soils.

TABLE 1

Preventative Maintenance

These are the five principle activities to our preventative maintenance process.

Activities	Functions	Performance Evaluation Criteria	Cost Justification Factors	Alternatives
1. Video Inspection	1. Identify locations and severity of debris accumulation, root infestation, infiltration sources and structural defects. 2. Assess the effectiveness of preventative maintenance activities. 3. Provide data for establishing a predictive model of the sewer system for the purpose of future maintenance rehabilitation planning and budgeting.		1. Improve the cost effectiveness of all the other preventative maintenance activities.	
2. Sewer Cleaning	1. Maintain sewer hydraulic capacity and prevent sewer backup. 2. Reduce sulfide buildup and extend the life of the sewer.	1. Number of sewer blockages. 2. Extended life of sewer.	1. Reduce basement flood damages. Minimize social and public health impact. 2. Extend life of sewers.	1. Design changes (eg., increase minimum slope). 2. Reduce the quantities of solid/grease discharging into this system.
3. Chemical Root Control	1. Retard root growth.	1. Effectiveness of root growth retardation.	1. Reduce sewer cleaning cost. 2. Reduce structural damages.	1. Relining the sewer. 2. Replace sewer.
4. Repairs	1. Maintain structural integrity and prevent further deterioration. 2. Maintain or restore adequate sewer hydraulic capacity.		1. Restore the function of the sewer.	1. Relining the sewer line. 2. Design changes (eg., use plastic pipe in alkali soil).
5. Infiltration/ Inflow Control	1. Reduce the sewage treatment plant operation cost. 2. Prevent sewer capacity overload. 3. Prevent erosion of backfill material in the pipe zone.	1. Quantity of infiltration/inflow reduced.	1. Savings in sewage treatment plant operation cost. 2. Eliminate the need for a relief sewer. Reduce basement floodings. 3. Reduce the number of future repairs.	1. Implement in conjunction with renewal/rehabilitation.

TLP/ew
C:Prevmain

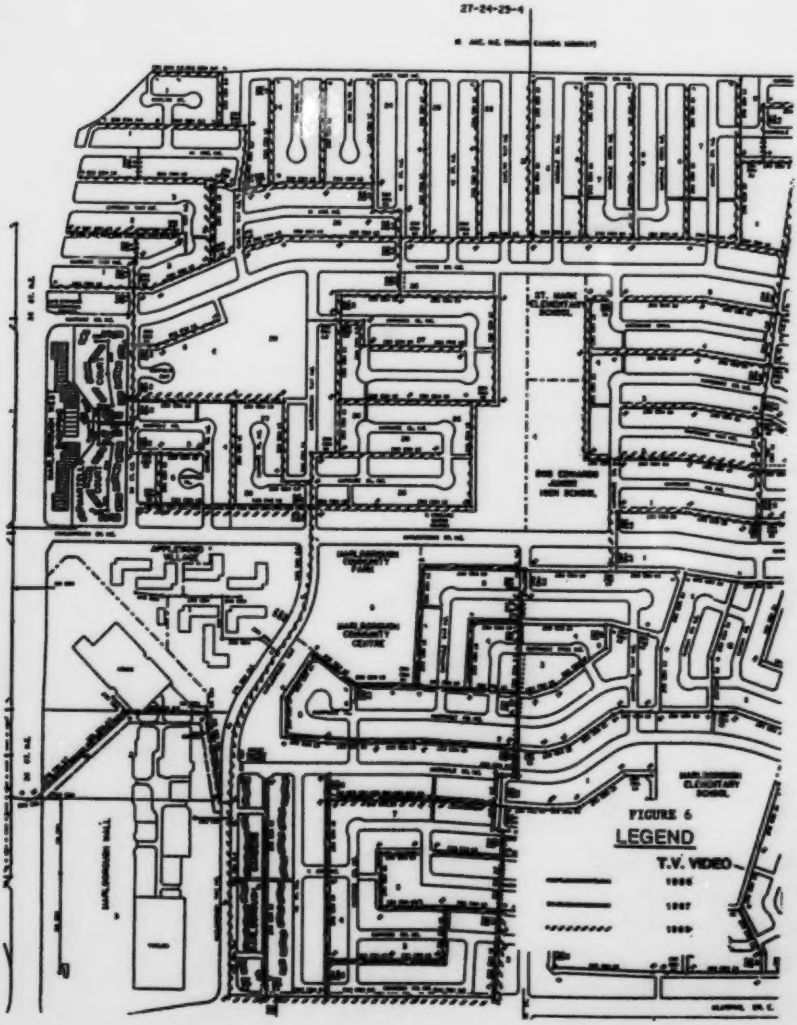

27-24-29-4
ST. MARK ELEMENTARY SCHOOL
HARLBOROUGH COMMUNITY PARK
HARLBOROUGH COMMUNITY CENTRE
HARLBOROUGH ELEMENTARY SCHOOL
LEGEND
T.V. VIDEO
1986
1987
1988

FIGURE 6

The TV inspection results are reviewed against maintenance and operation histories of the sewers to arrive at a plan for preventive maintenance or renewal/rehabilitation.

Root Control Program

We have a well defined root control program. Mechanical root cutting and removal has been used for 25 years. A review of root removal programs were undertaken in 1984 and a new method of root control was initiated. Video inspection identifies the severity of the root penetration. The severity is assessed and removal or herbicide application is recommended. Both sanitary mains and services are treated with herbicides. We will be reviewing the root control program in 1989 to assess the overall effectiveness and comparative cost between chemical and mechanical control.

Sanitary Services Treated

Year	Number of Services Treated	Trouble Calls in Previous Year	Trouble Calls Since Treatment	Replaced Since Treatment
1984	27	124	39	3
1985	45	60	22	3
1986	50	132	23	3
1987	78	175	7	3

Sanitary sewer mains treated under this program have shown a considerable decrease in trouble calls. Sanafoam Vaporooter is expected to prevent root regrowth for 3 to 5 years. It has not proven to be 100 percent effective; however, application over several years may approach this expectation. We currently have found 1000 chronic service connections that have a record of two to four trouble calls a year. If we assume an effective rate of 66 percent, we can expect a reduction of approximately 2000 trouble calls a year. The effectiveness of Sanafoam Vaporooter is expected to increase for secondary application.

Sanitary Mains Treated

	Pipe Size (mm)			
Year	150	200	250	300
1984		1665	790	
1985		700	1010	95
1986	400	1540	1250	
1987		3505	3962	97

Initial feedback indicates that savings can be realized from applying chemical treatment rather than mechanical root removal. We are presently making a 5-year evaluation of the root control program to determine cost effectiveness between chemical and mechanical root control.

Infiltration/Inflow Control

An infiltration/inflow control study concluded that it is not feasible to carry out a full-scale sewer system evaluation and infiltration reduction program because extraneous flow amounted to 20 percent at our treatment plants. Infiltration was not localized and was low relative to the total system. Long-term infiltration reduction is evaluated and implemented in conjunction with TV video-induced renewal/rehabilitation.

Currently we are conducting a 5-year pilot project to review the cost and effectiveness of maintenance and repair programs. The pilot project covers a small sanitary area of approximately 16 km. In this project, all work done in the experimental area is documented and the results evaluated. We hope to gain answers to such questions as:

Are overall maintenance activities achieving intended results?

Is the root control program effective?

Are we achieving the desired results at competitive costs?

Is cleaning required? Is the cleaning interval correct? Is cleaning effective?

Is structural deterioration occurring and at what rate?

PREDICTIVE ANALYSIS

The objective of this program is to evaluate the structural condition of the sewer system with respect to potential for failure in the immediate time frame and determine the remaining useful life. Examples of areas investigated are the degree of internal corrosion of sewer lines under attack by aggressive alkali soils, the degree of cracking of clay and concrete pipe, and the amount of groundwater infiltration for sanitary sewers, surface deterioration and the condition of access steps in storm and sanitary manholes.

This program also determines the condition of the infrastructure with respect to its ability to operate as intended, i.e., sewer mains conveying sanitary sewage without causing backups or collecting groundwater; the structural strength to withstand earth loads without collapsing; and the ability of manholes to provide safe access for maintenance to sewer systems.

We are initiating methods of predicting the remaining life of infrastructure as physical prediction models rather than statistical prediction models. This method involves the development of a model to predict the changes caused by environmental and operating conditions to the strength characteristics of the infrastructure. By defining the minimum strength required for the infrastructure to perform, the time-to-failure or remaining useful life can be predicted. Physical prediction methods involve physical testing of samples of the infrastructure as well as testing the effect of environmental parameters on the infrastructure.

We have soil resistivity readings that correspond to watermain problem areas. We are using this information for our predictive analysis in the hopes of developing some correlation between the action of aggressive soil and the condition of our sewer system. The correlation of alkali levels in the soil to the life expectancy would be a very useful relationship for predicting structure life.

Once a trend is established and a correlation between several variables becomes reliable, analysis can be performed to estimate the time to failure for the maximum practical life of our utilities.

By applying the unit costs to the life-cycle analysis of the various options available, the optimum repair/renewal program can be defined as well as the required budgets.

RENEWAL/REHABILITATION

All operating divisions of the Engineering Department have defined renewal/rehabilitation programs in the City of Calgary. The Structures and Buildings Division evaluates bridges and buildings, the Waterworks Division has an extensive main replacement program, the Streets Division reconditions roads by asphalt overlay, and the Sewers Division relines and replaces storm and sanitary sewers.

Two important elements of an effective renewal/rehabilitation program are:

1) the ability to predict the remaining useful life of the infrastructure, and

2) the development of an economic program to establish the time to replace the infrastructure rather than to continue repairing it.

Renewal or replacement by removal and replacing the old with new materials extends the life of the infrastructure only when a total replacement of the link between manholes is undertaken. Rehabilitation extends the life of the existing links by adding materials (coating, linings, etc.) to make the infrastructure as "good as new".

Evaluations to renew or rehabilitate are based on the information collected during the data collection phase. The utility is evaluated to ensure that the system is in service for the maximum practical length of time. It is our philosophy that repairs dealing with localized problems keep the local system in operation but have little impact on the service life of the entire system.

The time and resources required to establish the remaining service life of the utility will vary significantly with the accessibility of the infrastructure. Surveying the utilities on the surface, where accessibility is high, is considerably easier and less expensive than excavating through 3 m of soil to look at a buried utility or investigating the system remotely as one does with annual TV surveys. But the condition inside a pipe is not necessarily indicative of the condition the exterior of a pipe. Alkali attack at the soil/pipe interface may be extreme, whereas the attack on the interior may appear to be mild. Therefore, for a valid assessment, excavation is required.

Municipalities must be able to plan for the most effective renewal, not just to prioritize the most needy, but estimate the year in which an item reaches its anticipated design life and in which year it should be replaced. If the municipality has an established and reliable database and can successfully predict in what year the utility must be replaced, then an excellent long-term renewal plan and budgeting program can be met. The City of Calgary is moving in the direction of developing such a computer-aided program to estimate when to replace.

The majority of the replacements are in the areas where the utility was originally constructed more than 20 years ago, but even more are in the area of the city where utilities exceed 40 years of service life. The replacements in the northeast corner of the city are noted exceptions. The Waterworks Division has soil resistivity readings that correlate with actively corrosive soils. We have experienced alkali attacks on our sewer mains in the area and are monitoring them closely.

The life expectancy (based on accounting depreciation) of the sewer system for the City of Calgary is 40 years. However, most of the piping materials used for sewer construction can last longer. We have existing sewers installed in the 1900s that are still in service. However, we also have sewers originally installed in poor soils that have been replaced far short of their 40-year depreciated life expectancy.

Studies in England estimate the life expectancies of well maintained sewers in normal soil conditions as follows:

Diameter (mm)	Service Life (Years)
> than 1000	exceeding 125
300 to 1000	up to 125
< 300	up to 100

(G. Edward & G. C. Cox, 1982)

Our approach to identifying renewal/rehabilitation is based on TV inspection. We have six sewer districts in the City of Calgary and each district foreman compiles a list of potential replacements based on complaints received, service lead problems, cleaning frequency, main breaks, and plugs. Their recommendations are reviewed and the areas TV-inspected by experienced senior staff. Renewal/rehabilitation work is then prioritized with other scheduled work coincident with the Waterworks Division's main replacement programs and Streets Division's resurfacing programs.

Until 1973, the annual length of replacement was approximately 1000 m. During 1973 to 1983 the average annual length of replacement was approximately 2 km.

Infrastructure replacement/rehabilitation and development have steadily increased by 3.0 km in 1984, 4.4 km in 1985, 4.5 km in 1986, 4.2 km in 1987, and 5.6 km in 1988.

The renewal/rehabilitation program involves replacement by physically renewing the deteriorated utility with a new pipe of the same size or a larger diameter or by digging a hole and replacing the pipe. Rehabilitation has been completed by two techniques in the City of Calgary, slip lining and Insituform lining.

Rehabilitation with such linings have proven successful and cost-effective in that the cost has always been below the estimated costs of conventional replacement.

Year	Extent of Rehabilitation (m)	Size of Lining (mm)	Cost of Replacement ($x1000)	
			Insituform	Conventional (est.)
1986	405	200	40	125
1988	165	250	51.1	77
1987	246	200	35	133.2
1988	488	200	35.6	155

Cost savings of 25 to 75 percent have been realized by applying rehabilitation methods over total replacement methods.

CONCLUSION

Structural deterioration will cause the need for renewal or rehabilitation of much of the City of Calgary's sewer infrastructure. The Sewer Division is in the preliminary phase of developing modern techniques of maintenance and renewal/rehabilitation for the sewer infrastructure. The following conclusions will help in that development:

- The implementation of the SWIMS database will allow more effective systems analysis and the development of more effective maintenance/renewal programs. When the SWIMS modules are combined with JUMP, the City of Calgary will have an advanced computerized maintenance system.

- Older areas of Calgary are key areas for developing renewal/rehabilitation techniques in preparation for the future programs.

- The Sewer Division has used recently developed technologies such as slip-lining and Insituform lining successfully for sewer rehabilitation and is continuing to monitor their serviceability.

- Video inspection has been the key to the successful implementation of new technologies for sewer renewal/rehabilitation. The development and improvement in this area will benefit our database development for future analysis.

- The video inspection program verifies the areas in need of preventive and corrective maintenance.

- We have four defined preventive maintenance activities: TV video inspection, flushing and cleaning, control of root penetrations, and repairs.

- Preliminary long-term analysis indicates a need to continue the renewal/ rehabilitation program to control existing demand and meet future needs.

- The pilot program will provide much useful information about the development of future maintenance/renewal data as it applies to a city-wide application.

- The root control program is providing an effective method for reducing labour and expenditures on problem services and main sewers.

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PREVENTING CORROSION OF UNDERGROUND WATERMAINS

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ABSTRACT

By preventing the corrosion of underground watermains with cathodic protection or the use of zinc anodes or water-excluding wrapping materials, municipalities can reduce their watermain replacement budgets to 10 or 15 percent of present-day costs. Such means of corrosion prevention are designed to last for 25 to 30 years. Their installation often causes little upheaval.

RÉSUMÉ

En prévenant la corrosion des principales conduites souterraines d'alimentation en eau, grâce à la protection cathodique ou l'emploi d'anodes de zinc ou de matériaux enveloppants étanches à l'eau, les municipalités peuvent ainsi abaisser leurs budgets de remplacement des conduites d'eau de 10 à 15 p. 100 en dollars d'ajourd'hui. Une telle prévention de la corrosion devrait rester efficace pendant 25 à 30 ans, sans compter que sa mise en oeuvre cause peu de bouleversement.

INTRODUCTION

It is not necessary to replace existing cast- and ductile-iron pipes with plastic pipe. In fact, replacing cast- and ductile-iron watermains can create more problems than it solves, unless steps are also taken to prevent an increased rate of corrosion of the metals left, such as steel operating rods, brass shut off valves, and cast-iron valves with steel bolts. They are all susceptible to increased corrosion because the anode, namely, the cast- or ductile-iron watermains, has been removed and the electro-chemical reaction continues on the operating rods and the remaining metals comprising the service materials.

Replacement of the steel operating rods with stainless steel does not stop the corrosion process, the reaction will then move to begin the corrosion process once again, this time attacking the brass connectors.

The prevention of corrosion of underground watermains can help the municipalities in reducing their watermain replacement budgets to 10 or 15 percent of present-day costs by the installation of watermain cathodic protection or the use either of zinc anodes or of water-excluding wrapping materials. The system is designed for a life of 25 to 30 years and yearly tests ensure that the system is working.

All installations are now made in the boulevard or back alley when a boulevard is not available. And no excavation of paved areas is necessary, unless both the street and the back alley are paved, then removal of surface may be necessary for a length of approximately 100 ft. on a 500-ft. block to allow for ploughing of cable and drilling of holes 6 in. in diameter to insert the anodes to a depth of 9 or 10 ft.

The price equals the cost of one year's interest payment on the capital expenditure required for watermain replacement. The system merits consideration in any municipalities budget.

CATHODIC PROTECTION

The worst corrosion-created leakage problem we have ever tackled was a 500-ft. section of 8-in., ductile-iron pipe having 18-3/4" copper services, which had had nine leakage incidences over the previous 18 months. A corrosion-preventing system was installed 3 years ago and has had no corrosion leaks.

We have generally come to the conclusion that cast- or ductile-iron watermains need not be replaced because of corrosion, if their leak repair incidence is not greater than three to five leaks over the previous 12 months. In making our assessment, we take into consideration, of course, the probable life remaining in the existing watermain, such as type of watermain (cast- or ductile-iron), type and size of services, and location of leaks for the block under study.

Other considerations determine whether we can successfully prevent further deterioration of the main and reduce leakage to zero. To control the leakage, if upgrading is proposed, the cost of installing the cathodic protection system can be as low as the cost of one year's interest on the cost of replacement or 15 to 20 percent of the cost of replacement with plastic pipe. In fact, replacement with plastic pipe can cause even more problems, because replacement does not cure your corrosion problems.

Sure, the cast- or ductile-iron pipe does not corrode any more, because it is not there, and true, the plastic pipe does not corrode (although, the jury is still out on the long-term use of plastic pipe). But, the problem is that the replacement of cast- or ductile-iron pipe with plastic pipe only shifts the problem to the other metals used for such services as copper pipe, brass shut-off valves, steel operating rods, and other underground ancillaries, such as cast-iron valves and water hydrants.

To help you understand what has been the primary cause of corrosion of the underground cast- and ductile-iron watermains, we ask you to return to your high school chemistry and remember the experiment when two different metals immersed in an electrolyte, connected together, resulted in one of these two metals corroding while the other remained untouched. The flashlight battery, of course, depends on the same principal that if two different metals are connected, electricity is produced, resulting in one of the metals corroding and the other remaining unaffected.

In effect, these two examples illustrate cathodic protection whereby one metal is prevented from corroding by the other. Corrosion is an electro-chemical reaction involving the transfer of electrons from a negatively charged (anodic) area on the surface of a metal to a positively charged (cathodic) area. This reaction is activated only when the metal is exposed to a moist environment, such as condensation from humid air, water, or soil.

In the reaction, each atom of iron loses negative electrons, thus causing the atom to separate and become positively charged - it has become an iron ion. The positive ions are then attracted into their surrounding solution by negative ions, resulting in metal loss or corrosion. The electrons within the other metal attract positive ions in the solution to form a protective shield on the metal surface.

The control force or common denominator in the corrosion process is the electron. For all intents and purposes the electron is an invisible negatively charged unit of energy without physical properties and normally remains in the metal. Electrons always travel from negative to positive locations within a metal. The positive iron ions, on the other hand, have physical properties and their being drawn into the environment leads to metal loss. An understanding of which metals will corrode comes from the study of the galvanic series of metals (see Appendix). If a metal high in electron energy is connected to a metal low in electron energy and immersed in a electrolyte, the metal high in electron energy will corrode and cathodically protect the metal low in electron energy.

This scientific placement of various metals in the galvanic series illustrated what has been happening in our industry. When we study the galvanic series we can readily understand our history. First we had lead services attached to cast-iron pipe, and there was little or no corrosion. In fact, today in some areas I am asked the question "Why do we not have corrosion on our older downtown areas while we have corrosion on adjacent streets?" In many cases the answer is apparent, records indicate that there are still lead services in the old areas. And as you can see in the galvanic series, lead is almost like cast iron in electron energy. When we moved from cast-iron pipe to galvanized steel services, the steel services corroded. Steel is above cast iron in the series. Then we moved to copper services. Copper is low in electron energy. Thus, our present-day crisis began 25 to 30 years ago. It took the time to develop because of the mass of cast iron compared to the mass of copper pipe; however, their masses were reversed when we had galvanized steel services on cast iron. The same reasons discredit ductile iron installed to repair or replace cast-iron mains. The ductile iron corroded even though it was new pipe.

We have looked at the history and the causes, and seen the results of connecting different metals together underground.

The solution lies in understanding the galvanic series of metals and in selecting a metal which, if connected to the watermain system, would corrode and yet not be part of the watermain system. We selected zinc. It is high in electron energy and a relatively inexpensive.

The method of installation also had to be economical. Since we could not go digging up streets and roadways, it had to be an off-pavement installation.

The method of installation calls for ploughing cable 0.6 m underground within the boulevard area of the block to be protected, then auguring a designed number of high-output, packaged zinc anodes to a depth of 3.05 m. These are connected to the cable ploughed at predetermined distances apart and at locations previously decided upon. This bank of anodes is then connected by means of a single cable to the outside tap of one of the houses whose service is connected to the main being protected against corrosion. A test post is also installed, so that the cathodic protection system can be monitored.

After installation of the cathodic protection system, the incidence of beam breaks is in many cases also reduced to zero. At the soil plane, changes in soil occur, which set up galvanic corrosion cells due to differences in soil resistivities which weaken the metal in due time. The metal has withstood many changes of underground pressures due to frost over, say, 20 to 30 years before suddenly breaking. Therefore, we conclude the metal has weakened over this period of time, and the installation of cathodic protection prevents further weakening at these planes of soil changes.

Continuity tests and other tests are performed so that we can be assured that not only the main within the street area but also each and every service is protected. This depends, of course, on ensuring that the services are not electrically separated from the main. Services should not be separated. Corrosion may be reduced on the main but will only result in increased corrosion of the service metals, particularly the steel operating rods. Steel bolts on valve installations and hydrants are particularly susceptible.

CONCLUSION

I would like to leave you with the thought that there is no necessity to replace your existing cast- or ductile-iron pipe. To replace it may very well be a decision resulting in more problems than you planned to solve; particularly, problems concerning the corrosion of the other structures that would be left, such as valves, services, and other underground metal support systems for the watermains.

Cathodic protection also offers an alternative to excavating and tearing up pavements and roadways.

APPENDIX 1

GALVANIC SERIES OF METALS IN ORDER OF ELECTRICAL ENERGY

(IN MODERATELY CORROSIVE SOIL)

Metals	mV Cu/CuSO^4	Remarks
Magnesium	1500	High in
Zinc	1100	electron
Aluminum	1000	energy
Galv. Steel	900	- - -
Steel	700	
Ductile Iron	600	
Cast Iron	550	
Lead	500	
Brass	400	
Stainless St.	300	
Copper	200	
Cu/CuSO^4	0.00 Reference	+ + +
Silver	+250	Low in
Graphite	+350	electron
Gold	+1130	energy

ANALYSIS OF TRANSIENTS IN WATER DISTRIBUTION SYSTEMS

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ABSTRACT

The pressures generated by transient conditions (water hammer) in pipe systems can frequently be three or more times the value of normal operating pressures and therefore engineers must know if

- the size and strength of the required pipe is to be rationally selected,
- surge suppression equipment is to be logically sized, and
- system operating rules are to be intelligently specified.

However, transient conditions are almost totally ignored by most water supply utilities - an oversight that is undoubtedly a contributing factor in the enormous cost of repairing watermain breaks in Canada. (The annual cost exceeds $100 million.) If transient analysis is done at all, it is frequently subject to gross simplifications or assumptions are frequently made. Up until recently there has been little choice in adopting this approach because the generalizations and programming required to analyze transient conditions comprehensively have been either incomplete or prohibitively expensive. With modern computer techniques, however, it is now both possible and desirable to analyze distribution systems under a wide range of flow conditions and with far fewer restrictions than have been required in the past. Examples presented in this

paper demonstrate the danger of simplifying either the nature of the physical system or the operating conditions to which it is subject.

RÉSUMÉ

Les pressions qu'exercent les "coups de bélier" dans les réseaux de canalisations peuvent souvent être de trois fois ou plus supérieures à ce que subissent normalement les conduites en service; c'est pourquoi les ingénieurs doivent en savoir plus pour être ben mesure de :

- choisir judicieusement la section et la résistance de la canalisation requise;
- bien dimensionner le matériel d'élimination des surpressions; et
- préciser les règles de fonctionnement du réseau de façon intelligente.

La plupart des services responsables de l'alimentation en eau font presque totalement fi des surpressions passagères, négligence qui, sans aucun doute, explique le coût faramineux de réparation des conduites maîtresses d'alimentation au Canada, soit plus de 100 millions de dollars annuellement. Toute analyse soit-elle donne souvent lieu à des simplifications ou à des hypothèses aberrantes. Jusqu'à tout récemment, on ne disposait pas vraiment d'autre choix que de recourir à cette méthode, vu que la généralisation et la programmation requises pour analyser complètement les surpressions ètaient soit incomplètes, soit d'un coût prohibitif. Grâce à l'ère informatique, il est dorénavant à la fois possible et souhaitable d'analyser les réseaux de distribution d'après une vaste gamme de débits, compte tenu de beaucoup moins de restrictions auxquelles il fallait s'astreindre par le passé. Les exemples illustrés dans ce document démontrent bien les risques de simplifier la nature du réseau physique ou ses conditions de fonctionnement.

INTRODUCTION

Pressure pipe systems are subjected to a wide range of physical loads and operational requirements. For example, the underground piping systems must withstand internal and external corrosion, various forms of bedding stresses, including differential settlement, construction damage, local stresses at connections as well as other external and internal forces. As a result of this ongoing chemical and physical attack, both the hydraulic and structural capacity of the pipe is reduced with time until some kind of failure occurs. The failure may be physical in origin, such as a break which causes loss of water and pressure, or it may be economic, arising from increased fluid friction with its associated reduced flow capacity, increased power costs, or both.

One source of loading, which is commonly neglected in water distribution system analysis, is due to water hammer or transient conditions. Although it is well known that the pressures generated during transient conditions should be an important consideration when simple pipeline systems are being designed or constructed, transient studies tend to be neglected in distribution system analysis. However, if the size and strength of the required pipe is to be rationally selected, if the surge suppression equipment is to be logically sized, and if system operating rules are to be intelligently specified, then reliable transient analysis is essential.

Unfortunately, transient analysis is not easy. The governing equations describing the flow are of the non-linear partial differential type, the hydraulic devices are complex and data regarding their performance are difficult to obtain, and the pipeline systems themselves are subjected to a host of operating conditions and requirements. To make matters worse, the physical character of the pulse wave propagation is frequently hard to visualize or interpret, even for the analyst accustomed to interpreting transient conditions.

TRANSIENT ANALYSIS AND DESIGN

The complexity of transient phenomena has motivated many engineers to greatly simplify analysis in order to make the design tractable. This simplification takes place in two primary ways: (1) complications in the physical system itself are ignored or (2) the range of operating conditions to which the system will be subjected is greatly reduced. These simplifications are rationalized on the grounds of necessity (we cannot analyze the actual physical system) and conservatism (the system we analyze performs worse than the real system). Unfortunately, it is very difficult to identify a simplified system that will result in worst-case performance under all possible conditions, particularly if the simplifications are made before any analysis has been performed.

Traditional wisdom for identifying worst-case scenarios is based on elementary equations, rules of thumb, or common sense - simple ideas which may have little or no bearing on the performance of more complex systems. Several of the most common rules of thumb are presented in this paper along with counter arguments by example refuting them. However, the main thrust of the paper is this: comprehensive analysis of transients is both technically and economically possible. Only if the analysis is comprehensive can the whole range of loading conditions, to which an existing or proposed system may be subjected, be ascertained. In addition, this paper argues that the analysis should be performed on a realistic representation of the physical system without making unwarranted and possibly incorrect assumptions about components that can safely be neglected.

In the past few years the accuracy and efficiency of transient analysis has undergone many refinements and improvements. However, more attention has frequently been paid to how the analysis is performed than to what is being modelled. For example, many papers have been written on the relative accuracy and computational merits of various numerical procedures; far fewer have considered the sensitivity of transient conditions to the assumed initial state or to what kind of interaction between automatic control devices can lead to the most severe transient problems. While it should be pointed out that all of the warnings and many of the examples presented in this paper have been known for many years, in practice there has been a tendency to rely on a priori assumptions of what constitutes good transient design. These a priori assumptions may well be valid under some circumstances. But given the substantial initial investment associated with pipeline systems and the considerable cost associated with system failure contrasted with the relative cheapness of computer resources, there is little reason to be presumptive. In many applications, comprehensive transient analysis is justified.

Several of the examples presented in this paper are based on analysis of the City of Calgary's water transmission and distribution system. The Engineering Department of the City of Calgary is pioneering a comprehensive investigation of transient conditions in its large and sophisticated pipe network. The purpose of this study is to rationally identify those conditions under which transient pressures are most severe and to investigate the influence of various remedial strategies. This information may have significant implications for the design, protection, and operation of water distribution systems.

TRANSIENT PHENOMENA

Fluid Properties and Their Implications

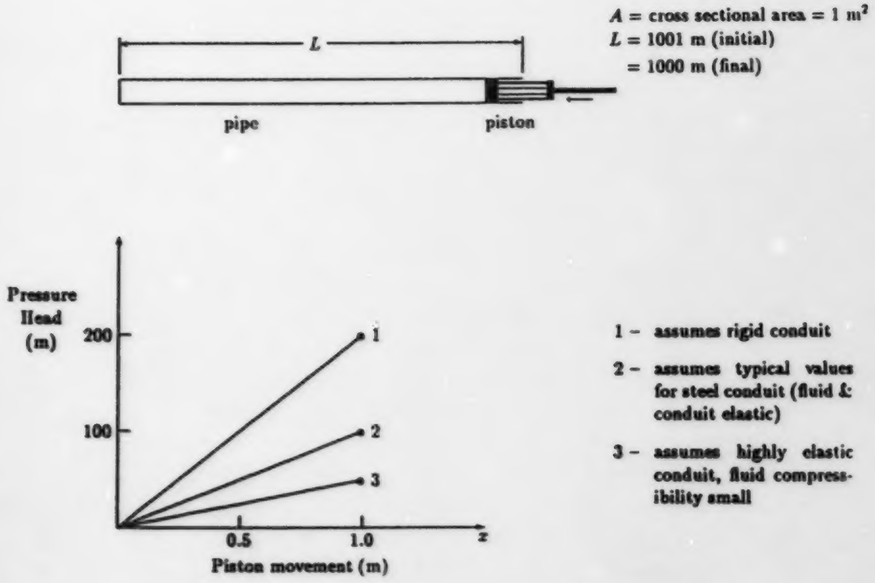
Liquid water is immensely heavy and very difficult to compress. What is not obvious, however, is that these two properties go a long way to explain why transient pressures can be so large and under what conditions the largest pressures tend to occur.

Liquid water has a density of approximately 1000 kg/m^3 under normal temperatures and pressures. As a result, water pipelines tend to contain vast amounts of mass, momentum, and kinetic energy. For example, consider a closed conduit 1000 m long and 1 m^2 in cross-section carrying water at 1 m/s. This pipeline contains 1000 m^3 of water having a mass of 10^6 kg, a momentum of 10^6 kg•m/s, and a kinetic energy of 500,000 J. Clearly, since such large amounts of momentum are involved, Newton's second law requires that equally large forces change the flow velocity for the entire pipe. This is particularly true if the changes in velocity are to take place rapidly.

But how can these large forces be generated? In open-channel flow it is possible to change the elevation of the fluid surface and produce a surge wave which will propagate in the channel. In essence, this wave uses the force of gravity to accelerate or decelerate the free-surface flow. However, when water flows or is contained in a closed conduit, no free surface is present and it is not possible to lift the fluid against gravity (unless the pipe breaks). The only location at which gravity might play a role is in devices such as reservoirs or surge tanks at the ends of the pipe. But even here changes in elevation can take place only relatively slowly as a result of mass accumulation taking place over a period of time. To generate large forces rapidly a different mechanism is required, and it is here that the compressibility of water plays such a vital role.

To understand the significance of compressibility in closed-conduit applications, consider Figure 1. Imagine placing a piston in a closed conduit as shown and then measuring the change in fluid pressure (head) as the piston is slowly moved in the pipe. The resulting head change will be a function of how far the piston is moved and how elastic the pipeline is. Typical values of both parameters are shown in the accompanying graph. It should be clear, however, that any movement of the piston, no matter how slowly accomplished, must be accommodated by changes in fluid density or conduit dimension, or both. In the literature it is often stated that Cauchy and Mach numbers (which relate fluid speed to the speed of disturbance propagation) are a natural index of the importance of fluid compressibility. For flow in closed conduits, however, these numbers are meaningless. Compressibility effects must occur whenever the amount of fluid confined in a pipe is changed. Thus, compressibility is important whenever there is a mass imbalance in a conduit so that more fluid enters the line at one end than leaves at the other. In addition, the greater the mass imbalance, the more severe the resulting pressure changes will tend to be. In anticipation of ideas to be broached subsequently, it could be suggested at this point that mass imbalance constitutes a more natural and theoretically satisfying criterion for establishing the severity of the transient response in the system than fluid velocity.

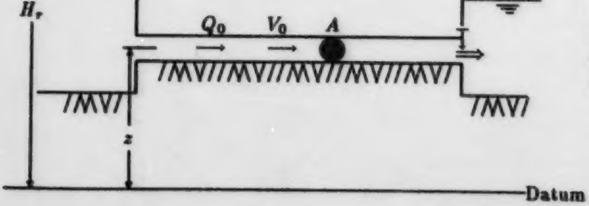
Figure 1: Relation between fluid compressibility and pressure head in a closed conduit.



The Origin of Transient Conditions

The relationship between fluid properties (density and compressibility) and the law of mass conservation is fundamental to an understanding of fluid transients. Suppose, for example, an adjustment is made to a valve at the downstream end of a pipeline carrying fluid at a certain initial velocity (see Figure 2). For simplicity, assume the valve is suddenly closed. The valve, of course, can only act locally - it specifies a relationship between flow through the valve and the head loss across the valve. In this case, the discharge and velocity of the fluid at the valve become zero the instant the valve is shut. However, in order for the fluid mass as a whole to be stopped, a decelerating force sufficient to eliminate the substantial 10^6 kg•m/s of momentum must be applied. The only way to provide the required decelerating force is to compress the fluid, thereby generating an increase in pressure large enough to arrest the flow of the fluid. Since water is heavy, the required force is large; but because water is only slightly compressible, the wave or disturbance will travel quickly. In a system such as the one shown, a pressure wave of approximately 100 m would propagate up the pipeline at roughly 1000 m/s.

Figure 2: Two constant head reservoirs joined by a series pipeline with a downstream valve.



$A = 1\ \text{m}^2$
$L = 1000\ \text{m}$
$\rho = 10^3\ \text{kg/m}^3$
$\gamma = 10^4\ \text{N/m}^3$
$g = 10\ \text{m/s}^2$
$Q_0 = 1\ \text{m}^3/\text{s}$
$V_0 = 1\ \text{m/s}$

In many ways, this system is quite typical. Closed-conduit systems frequently carry huge amounts of momentum and kinetic energy and, in addition, hydraulic conditions are in an almost continual state of change. For such systems, the only available mechanism for controlling or changing the flow conditions is by shock wave propagation resulting from fluid and pipeline elasticity. Only if the changes in flow conditions take place very gradually, so that the mass imbalance in the line is always small, is it possible to go gradually from one steady condition to another. Under these circumstances, no large fluctuations in pressure head or velocity will occur, since the pipeline is always very near a condition of equilibrium.[1]

However, if rapid changes occur, whether caused by standard operating procedures or accidental events, a relatively large mass imbalance may arise. The associated pressure pulses are of high magnitude and capable of bursting or damaging pipelines. To actually model or predict these rapid transient phenomena, complete equations of motion need to be written for both the pipeline and all the devices used to control fluid flow. However, the details of the more complete description should not be allowed to obscure the fundamental insight that more basic considerations provide. Transient conditions arise from local disturbances to the fluid flow that create a condition of mass imbalance. This mass imbalance then acts through the combined effects of fluid and pipeline elasticity to accelerate the flow and, ultimately, create a new steady state.

Special devices that are designed to control or eliminate transient effects should be viewed with some caution. It is the physical nature of the control problem that not only dictates that transient conditions must occur but that frequently also determines how dramatic transient conditions will be. Often, as in other areas of engineering, no design may be superior from all points of view. Instead, there may be compromises where a degree of control under some circumstances has been traded off for less control under others. Before proposing how to properly account for transient conditions, it is worthwhile considering how transients have traditionally been viewed and why this traditional approach is inadequate.

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[1] Even in cases such as this, however, the actual mechanism for maintaining equilibrium in the pipe is still mass imbalance and compressibility effects. The only difference is that the pressure waves are much smaller in magnitude and travel very quickly relative to the changes that occur at the ends of the conduit. In such applications, it is often justified to approximate transient behaviour by assuming the fluid to be incompressible. Neglecting fluid compressibility leads to the so-called 'rigid water column' model.

FOLKLORE ABOUT TRANSIENTS

Much traditional wisdom has evolved over time on how to cope with the complexity of transient phenomena. This wisdom often pertains to design assumptions which simplify the analyst's task by restricting the number and complexity of transient cases that need to be analyzed or specified. However, in the light of modern computer power, the rationale for these assumptions needs to be questioned. Indeed, many of the a priori design assumptions are so misleading and so frequently false that they should not be regarded as rational design rules at all, but rather as an outdated and discredited transient folklore.

Several of these misconceptions are addressed and, by means of counter-arguments by example, their potential for erroneous application becomes clear. To avoid misleading the casual reader, the title of each topic will be stated as the converse of the often improperly understood and applied design axiom. The account which follows is in no way exhaustive. The intention is primarily to refute some commonly accepted (axiomatic) design guidelines.

Perhaps the three most widely revered axioms of transient folklore are:

1. maximum velocities (flows) produce maximum head change,

2. networks make it better (that is, branched or looped configurations alleviate water hammer); and

3. if one surge protection device is good, then two (or more) are better.

The examples to follow were neither difficult to find nor have they been substantially altered to make the results contradict the aforementioned axioms. They simply demonstrate that there are important cases when these guidelines are either false or, at the very least, misleading.

Like much of what is called folklore in other areas, the axioms about transients stated above do have some basis in fact. For example, the origin of the first two axioms can be traced to the famous fundamental equation of water hammer, also called the

Joukowski relation. This relation equates changes in pressure head (Δh) in a pipe to the associated changes in fluid velocity (v):

$$\Delta h = \pm \frac{a}{g} \Delta v \tag{1}$$

where,

a = the wave speed
g = the acceleration due to gravity

Clearly, this equation implies that the greater the value of v the greater the resulting change in pressure head (h). Since the maximum possible change in velocity occurs when the initial velocity is greatest, then it appears that the first rule stated above must apply. In addition, networks carry flow in parallel lines and must make it more difficult to change velocity quickly and must attenuate pressure surges by causing wave reflections at junctions. Therefore, the second rule appears also be true. However, the logic leading to these two rules is faulty and the conclusions are dangerous.

An expression such as the Joukowski relation is only applicable under very restricted circumstances. In particular, there must be no head loss due to friction and there should be no wave reflections. If these conditions are not met, the expression is no longer valid. In addition (and what is more frequently forgotten), the conclusions based on this rule may no longer be valid.

Maximum Velocities Do Not Necessarily Mean Maximum Heads

A simple, convincing, and elegant demonstration of the limitations of the Joukowski relation can be found in the two-reservoir series pipe and downstream valve system shown in Figure 2. Let the closure behaviour of the valve be given non-dimensionally by its r-curve which describes the relative valve opening as a function of time. Let the length of the pipe = 1000 m, its wavespeed = 1000 m/s, and its diameter = 0.75 m. The following four cases are simulated over a 16-s time period (*Ho* is the reservoir head and f is the D'Arcy-Weisbach friction factor):

1. $H_o = 20$ m and f = 0.010

2. $H_o = 20$ m and f = 0.500

3. $H_o = 60$ m and f = 0.010

4. $H_o = 60$ m and f = 0.500

Under each of the four conditions, the rate of valve closure remains constant at 16.67x per second. In other words, it takes 6 seconds to close the valve completely from full opening (r = 1). Figure 3 shows the variation with time of the valve end pressure head, the valve end discharge, and the gate opening as given by *T* for (a) closure from full opening and (b) closure from one-third opening.

The bottom graph of Figure 3 indicates that the rate of valve closure is identical in both cases but that the partial closure takes only 2 seconds to complete. Note that the initial flow rate, due to the throttling effect of the partially closed valve, is much smaller than the initial discharge through the fully open valve. Despite the fact that the flow rate is significantly smaller in the case of partial closure, the head increase at the valve is much greater (top graph of Figure 3). This apparent contradiction of Equation 1 arises because reflected waves have no opportunity to attenuate the peak pressure at the valve as they do for the case of the closure from full opening. The head rise for the closure from one-third opening could be approximately predicted by Equation 1 for the low-friction case. This is so because the pipeline period of *2L/a* is equal to the closure time of 2 s. In other words, the first low-pressure wave to be returned from the reservoir would not reach the valve until it had just exactly closed and no destructive wave interference would be possible before the change in maximum velocity had occurred.

It is perhaps more instructive to perform this experiment for a number of gate closures from different partial openings. The rate of valve closure remains, as before, constant. The results of a number of such experiments are plotted in dimensionless form in Figure 4. The non-dimensional velocity (v) is the initial fluid velocity (discharge) divided by the steady-state velocity (discharge) in the pipeline with the valve fully open. The dimensionless pressure head at the valve (*h*) is the maximum pressure head achieved (at the valve) divided by the upstream reservoir head.

The key feature to observe in Figure 4 is that the maximum head rise does not occur when the velocity (discharge) is at its maximum possible value of v = 1. The belief, fostered by the Joukowski equation, that maximum flow rates constitute a worst-case condition is not justifiable. It should be emphasized that these valve closure results are well known; it is the implication for more complex systems that has been forgotten.

Figure 3: Valve action and transient response of the single pipe system to valve closure from full and partial (1/3) openings. Head and discharge values are given at the valve end of the pipe.

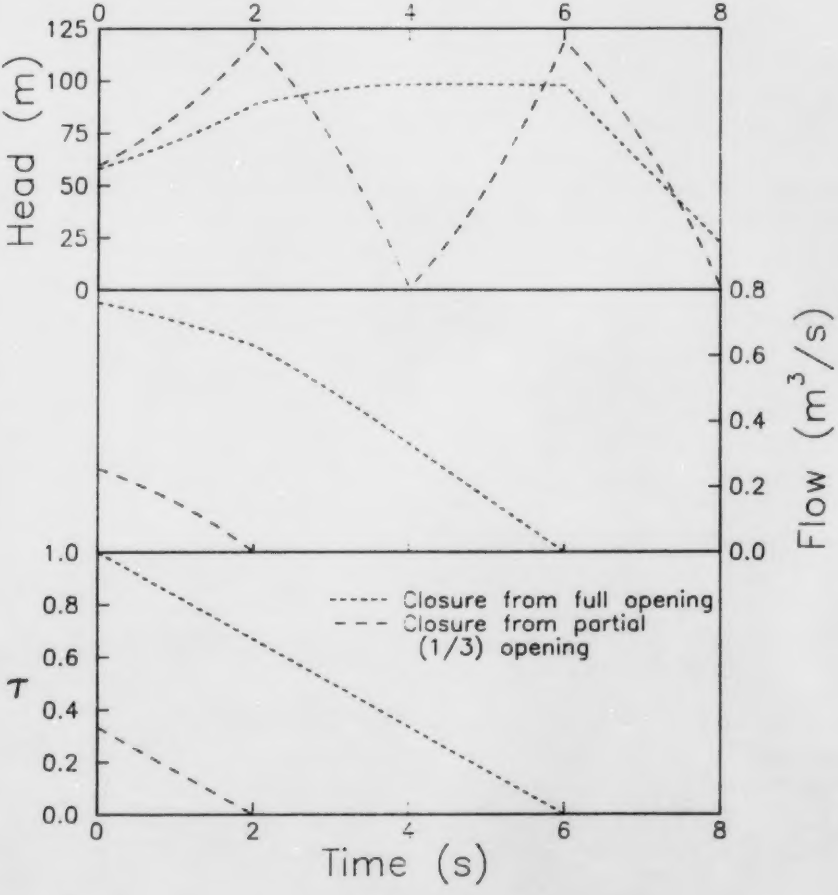
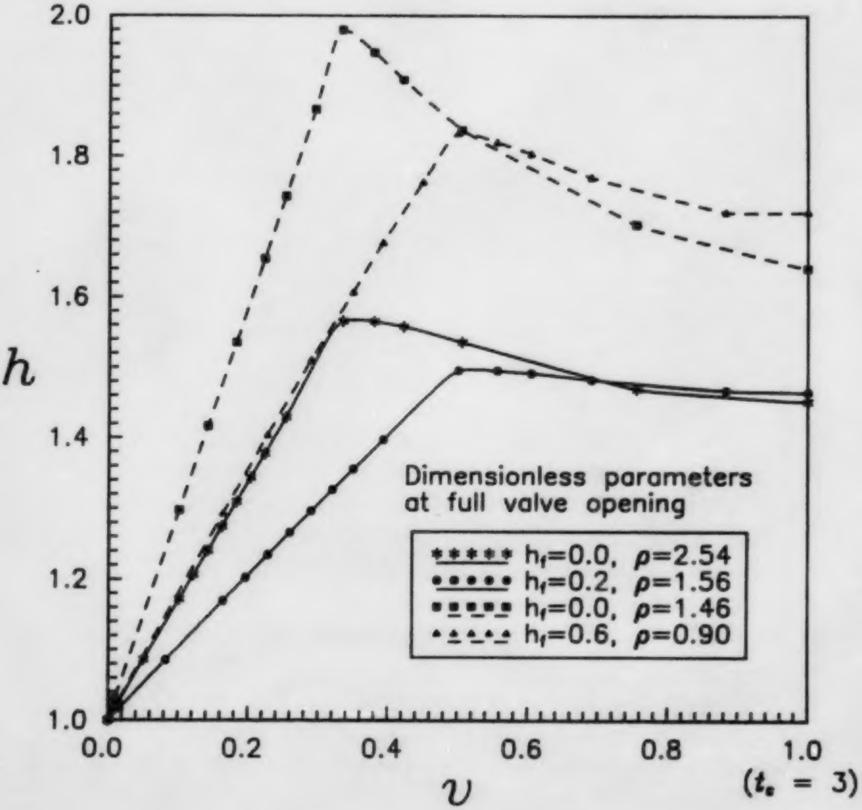


Figure 4: Effect of valve closure from partial openings on maximum head at valve end. (ρ = pipeline constant = $aV_o/2gH_o$, h_f = relative friction loss = H_f/H_o; t_c = dimensionless closure time = $T_c(s)/(2L/a)$)



Fluid transients are not only influenced by the fundamental physical characteristics of the system; their intensity and behaviour depends heavily on a host of other factors such as system configuration, timing of events, initial conditions, and many others. The next example of a myth about transients brings this point into even sharper focus.

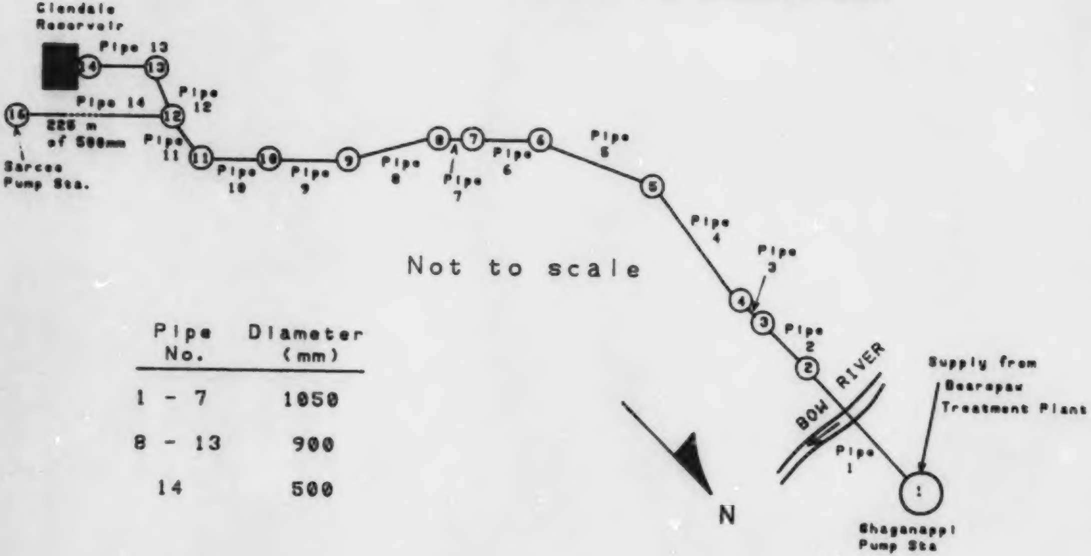
Networks May Not Improve System Transient Response

Many analyses of transients involve networks in which one line (a major feedermain with some minor branch connections, for example) is considered to be of overriding importance in determining the transient behaviour of the system. In such cases, it is often assumed that a conservative approximation results from considering the major line in isolation, provided that

1. all of the flow (in the analysis) passes through the main line, and
2. the actual branch flows are small compared to the discharge of the feedermain.

Implicit in this supposition are two things: (a) that maximum velocity produces maximum head changes and (b) that the existence of branch pipes in the actual system will to some extent absorb the water hammer. That is, it is assumed that the branch line capacitance will act in a manner somewhat similar to a surge tank. The dangers inherent in the first assumption have already been indicated. The problem with the second assumption is that the wave transmission and reflection properties of the branch line(s) are being entirely neglected. Figure 5 is a schematic plan view of the Glendale feedermain in the City of Calgary, Canada. Treated water from the Bearspaw water treatment facility at the northwest edge of the city is pumped along the Bow River Valley to the Shaganappi booster pumping station. The Glendale line itself consists primarily of reinforced-concrete pipe, 1050 mm (42 in.) and 900 mm (36 in.) in diameter, with some short steel sections in the vicinity of the river crossing. The line climbs approximately 135 m over its nearly 6-km length and terminates in the Glendale storage reservoir. Under most operating conditions nearly all of its approximately 80-ML/d (18-MIG/d) capacity passes from the Shaganappi pump station into the Glendale reservoir. Only one of the three minor connections which occur along the line has been shown in Figure 5. This is a 500-mm (20-inch) reinforced-concrete line which has a length, say, of 225 m (the actual connection, which runs to the Sarcee pump station, is roughly 1000 m long).

Figure 5: Plan sketch of the Glendale feedermain.


Glendale Reservoir
Pipe 13
Pipe 14
225 m of 500mm
Sarcee Pump Sta.
Pipe 12
Pipe 11
Pipe 10
Pipe 9
Pipe 8
Pipe 7
Pipe 6
Pipe 5
Pipe 4
Pipe 3
Pipe 2
Pipe 1
BOW RIVER
Not to scale
N
Supply from Bearspaw Treatment Plant
Shaganappi Pump Sta
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

Pipe No.	Diameter (mm)
1 - 7	1050
8 - 13	900
14	500

When the Shaganappi pump station is operating, this branch line is effectively a dead-end pipe, since the Sarcee pumps are only used to supply the Glendale line when the Shaganappi pumps are inoperative.

This system could be modelled under the conservative single-line assumptions mentioned previously. To illustrate the effect that adding the branch pipe (connecting Nodes 12 and 16) has on the transient initiated by a loss of power to the Shaganappi pumps, the Glendale feedermain has been modelled with and without the branch connection. Because the branch line is a dead end, all of the discharge from the pumping station still passes into the downstream reservoir during steady-state pumping.

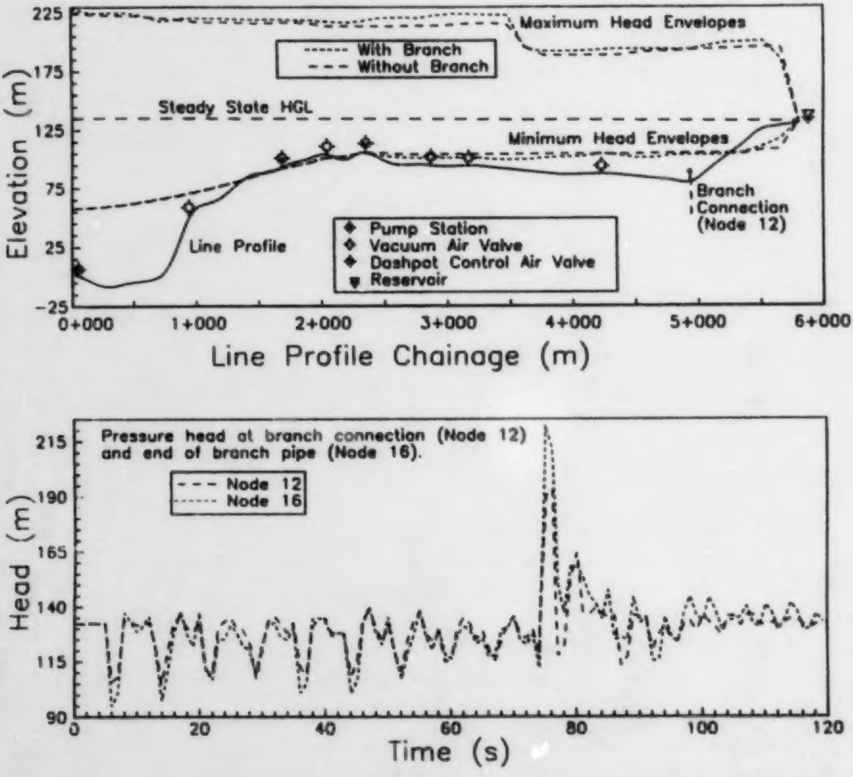
A useful way of summarizing the results of a transient analysis is to record the maximum and minimum pressures that occur throughout the system over the period of simulation. These values may be plotted along the length of the pipeline and produce an envelope delimiting the range of pressure variation at a particular location. The maximum and minimum pressure head envelopes developed in this way are plotted in the top graph of Figure 6. The results given correspond to the two cases of interest, namely, with and without the branch line at Node 12.

The plot also indicates the (initial) steady-state hydraulic grade line, the profile of the pipeline as well as the location of the Shaganappi pump station, several air valves, and the Glendale reservoir.

The dashpot control air valve shown at Station 2+280 m (elevation: 107 m) is one of the primary determinants of the Glendale feedermain transient behaviour. As the pump speed begins to dwindle following the power trip, a low-pressure wave is transmitted from the pump station towards the reservoir. This falling hydraulic grade line reaches the elevation of the air valve at Sta 2+280 and causes it to admit a large quantity of air into the pipe in order to maintain the line pressure at near atmospheric conditions. [Two other air valves are similarly activated (Sta 1+650 and Sta 2+040), but their associated air cavities are small and less influential in obtaining the peak pressures.] The large air cavity collapses after approximately 72 s have elapsed and the impact of the rejoining water columns causes a sudden and severe pressure increase.

The travelling wavefront caused by this event can be clearly seen in the pressure head trace of Figure 6 (bottom graph) as the surge reaches the branch connection a few seconds later en route to the reservoir. A portion of the wave is transmitted into the

Figure 6: Top--Profile of the Glendale feedermain showing maximum and minimum transient head envelopes, and steady state hydraulic grade line. Bottom--Pressure head traces at branch connection (Node 12) and at end of branch pipe (Node 16).



branch pipe. Upon reaching the dead end of the branch pipe, the initial pressure change doubles in magnitude and returns toward the feedermain. The pressure trace of Figure 6 shows that the head changes are more extreme at the end of the branch pipe (Node 16) than at the branch connection (Node 12). The cycle of high- and low-pressure fronts thus produced travel back into the main line and interact with other waves, causing constructive interference in some regions and destructive interference in others.

The overall effect of the wave interactions can be seen from the differences in the extreme head envelopes for the branched and non-branched lines. Although the increases in maximum pressures with the branch line present are (in this case) modest, the point is clearly made that ignoring the presence of branched or looping pipes does not necessarily result in a more conservative analysis. Also, is the hydraulic grade line elevation at the nodes where these attachments occur a particularly is not reliable indicator of the pressure heads to be expected in the omitted pipes as evidenced by the 30-m (45-psi) discrepancy in peak heads observed at bottom graph of Figure 6.

The final example to be presented extends the ideas introduced so far beyond the purely physical aspects of the system. Operational and functional considerations can take precedence over other factors in establishing the appropriate type and degree of protection needed against transients to ensure a reliable system.

More Surge Protection is not Always Safer

In most civil engineering systems it is axiomatic that overdesign implies a higher degree of safety. It seems strange that the converse could ever be true, but in hydraulic transient design, such a situation is neither impossible nor uncommon.

The preoccupation with maximum velocity as a critical case for water hammer obscures the fact that several factors working in concert at low values of discharge can also produce disastrous consequences. A case in point is the operation of surge-anticipating valves installed to protect against excessive pressures following pump failure. As mentioned in the previous example, loss of power to the pumps initiates a low-pressure wave as the momentum of the water column in the pipe continues to move the fluid in the absence of any motive force (apart from the inertia of the pump impeller and rotor). Surge-anticipating valves derive their name from the fact that they open in response to this low-pressure condition and so are able to provide maximum pressure relief when the returning high-pressure reflection reaches the pumps.

Surge-anticipating valves are usually installed in pairs, one serving as a backup to the other in the event that the second either fails to function properly or is not in service during the power outage. If the valves are well maintained and properly installed, they will both open at some preselected value of low pressure as the dynamic head of the pumps decreases following a power trip. What is often not realized, though, is that an opening valve produces its own downsurge which causes an additional drop in the hydraulic grade line. The effect is naturally greater when two valves open. This increased downsurge may cause other devices that react to low pressure to be activated and these, in turn, can alter the transient behaviour of the system.

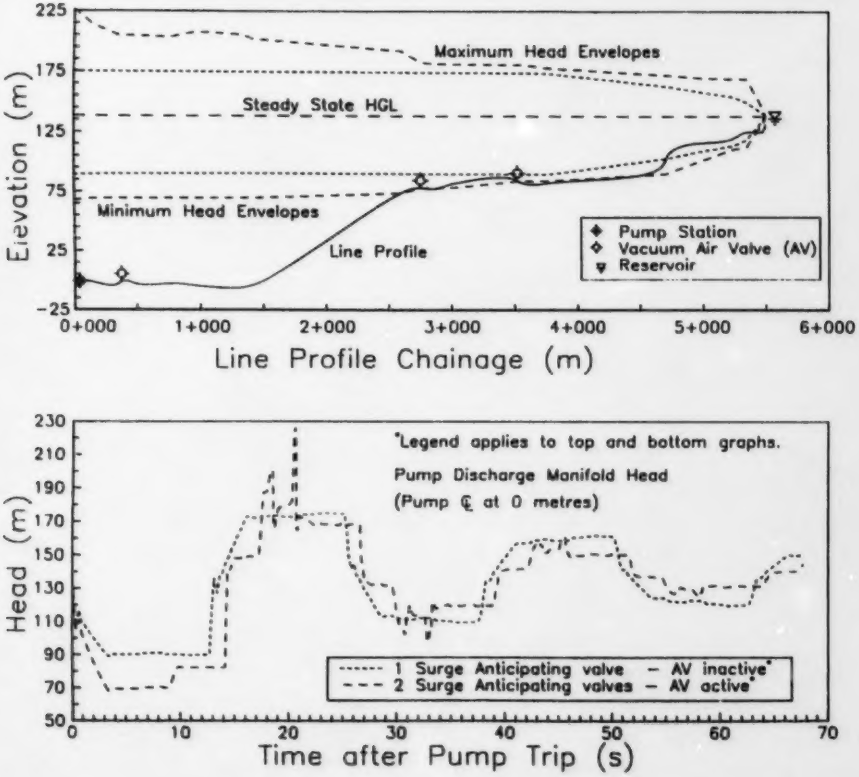
The upper graph in Figure 7 shows extreme pressure profiles generated in a hypothetical line for the scenario just described. This test system is identical to the one at the City of Calgary's many major feedermains, except that one of the high-point air valves has been changed from dashpot control (slow-closing) to a standard vacuum air valve. For the simulation results presented, only one pump supplying approximately 30 percent of the total pumping capacity of 95 ML/d is operating. The 5.5-km reinforced-concrete pipeline has a nominal diameter of 1350 mm (54 in.) and undergoes an elevation gain of just over 130 m.

In the case of a single surge-anticipating valve operating, the minimum position of the hydraulic grade line is above the elevation of the air valves so that they do not open. Thus, no water column separation occurs and the maximum and minimum pump discharge manifold pressure changes are 30 and 36 percent of the total dynamic head respectively.

If a second surge-anticipating valve is included in the pump station, the maximum downsurge at the pump increases to about 50 percent of the total dynamic head. The result is that the hydraulic grade line drops below the elevation of the air valve located on the rising portion of the pipeline (Sta 2+750) and water column separation takes place. The water columns rejoin as the air cavity collapses and a potentially calamitous pressure spike ensues. The increase in pressure head of the maximum discharge manifold rises to nearly 70 percent of the total dynamic pumping head. Details of the varying pump discharge manifold pressure head can be seen in the bottom graph of Figure 7.

Without performing additional analyses, it is not clear whether the system performance is worse when operating at full capacity with two surge-anticipating valves. In any event, the purpose of the illustration is not to decide the issue of which set of

Figure 7: Top--Profile of the hypothetical feedermain showing maximum and minimum transient head envelopes, and steady state hydraulic grade line. Bottom--Pressure head traces at the pump discharge header for one and two surge anticipating valves.



operating conditions constitutes the worst case. On the contrary, it should emphasize the question,"Is there a worst case?" in the context of transient analysis. Transients, even in relatively simple systems, are complex phenomena whose behaviour is governed by fluid properties, the physical setting, topology, location, service condition, and mode of operation of installed devices. If we add to this list data and model uncertainty, the stochastic nature of the (initial) state of the system and the sensitivity of system response to all of these factors, one might despair of gaining any meaningful qualitative or quantitative insight into transient phenomena. Happily, the prospects are anything but dismal.

Whereas the inherent immensity of realistic transient computations in the past compelled analysts to adopt many of the simplifying assumptions just discussed, the current state of the art is much less restricted. As in other technical fields, the advent and spread of cheap and plentiful computer resources is having a profound impact on fluid transient analysis. Analysis of only a few potentially misleading worst-case scenarios, based on some shaky rules of thumb, are no longer an imposed necessity. The relatively complex lines of the last two counter-arguments required approximately 3 and 10 minutes respectively to run on an IBM AT personal computer with an Intel 80287 chip. The time needed for the particular computer run depends on the selected time step, the complexity of system components, and the specified simulation duration. These figures suggest that the benefits of comprehensive transient capabilities are at hand.

CONCLUSIONS

Transient conditions play an essential role in the operation of pipeline systems. The only mechanism whereby flow conditions within a closed conduit can change is through the generation of transient pulses which, effectively, communicate or transmit information about changing conditions throughout the hydraulic system. If flow conditions change slowly, the resultant pressure changes are small and do not threaten the line in any way. However, if conditions change rapidly, very large pressures can be generated, frequently of sufficient magnitude to burst pipes and damage equipment. Power failure of pumps, sudden valve actions, and the operation of automatic control systems are all capable of generating high-pressure waves in domestic water supply systems.

The current practice has been to ignore transient conditions in large networks or, occasionally, to contract out particularly obvious problems relating to transients. If transient analysis is done at all, gross simplifications and assumptions are frequently made to render the analysis tractable. Until recently, there has been little choice in adopting this approach. The generalizations and programming required to do a comprehensive analysis of transient conditions have been either incomplete or prohibitively expensive. This is no longer the case.

Of course, transient analysis is not a sovereign remedy for all hydraulic problems or pipe system failures. The exact reason for which a given pipe fails is often complex and can be related to corrosion, earth pressures, construction faults, and other causes. However, transient pressures are sometimes great enough to fail new and strong pipes directly; weakening the pipe for any other reason simply makes the pipe more vulnerable to failure. Thus, in causing pipeline breaks, transient conditions play a dual role: they can rupture a pipe directly through excessive pressure or they can contribute to an existing weakness to fail the pipe indirectly.

MILL WOODS (CITY OF EDMONTON) STORMWATER DETENTION FACILITY

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ABSTRACT

To alleviate basement and surface flooding resulting from a heavily surcharged storm trunk system, the design and construction of a major stormwater detention facility was undertaken as a centrepiece to a series of recommendations for system enhancement. The facility was constructed within an existing city park and adjacent to existing recreational facilities in a built-up area. It serves as a stormwater management facility while preserving and enhancing the recreational amenities within the park. The facility consists of two interconnected lakes, a wet and a dry pond, a flow-regulating chamber, extensive landscaping, park amenities, and shallow storm sewers built within immediately effected areas.

The project involved a number of distinctly different challenges: the technical concerns of providing a functional stormwater relief system, the integration of recreational amenities with the stormwater management function, and the completion of the facilities within a restricted time frame and with a minimum of inconvenience for the residents.

RÉSUMÉ

Pour enrayer les inondations tant des sous-sols d'habitations qu'en surface occasionnées par une forte surcharge du réseau d'égouts pluviaux, on s'est livré à la conception et à la réalisation d'un important bassin de rétention des eaux pluviales figurant au coeur d'une série de recommandations axées su l'amélioration du réseau.

Établi dans un parc municipal déjà aménagé, situé tout à côté d'installations récréatives d'un secteur bâti, le bassin sert à contrôler le débit des eaux pluviales tout en préservant et en rehaussant les installations récréatives à l'intérieur du parc. Il s'agit en fait de deux lacs communicants, d'un étang à flot et d'un étang à sec, d'un bassin de régularisation du débit, de vastes aménagements paysagers, de commodités propres au parc, et d'égouts pluviaux peu profonds desservant les secteurs directement touchés.

La réalisation de ce projet pose différents défis : le souci technique de décongestionner le réseau pluvial, d'intégrer les commodités récréatives au processus de régularisation des eaux pluviales, et d'achever les travaux dans un délai restreint, en causant le moins de désagréments possible aux résidents avoisinants.

INTRODUCTION

General

The Mill Woods area is situated in the southeast of the city and has a total area of 1,100 hectares (4,000 acres); it is predominantly residential in nature. Development of the area started in 1970 and is still continuing. The area is located at the upper end of a single-trunk sewer that runs along 30th Avenue, approximately through the middle of Mill Woods, and varies in size from 2 m (78 in.) to 3.8 m (112 in.).

Recent History

In 1978, the area was hit by a major storm, one with an estimated return frequency of 1 in 200 years, and extensive flooding occurred. Then in 1983, two more storms of much lower return frequency, 1 in 8 years and 1 in 12 years respectively, struck. Both caused flooding.

In 1984, Edmonton Environmental Services (then Edmonton Water and Sanitation) undertook a comprehensive study of the existing storm system in the Mill Woods area using the Stormwater Management Model (SWMM) Version II. Results for a 2-year and a 5-year design storm sewer showed that, while the lateral/collector system was adequate, the storm trunks were heavily surcharged during a 5-year event and that even during a 2-year event certain sections of the trunk system have capacity constraints. In addition, the area does not have a well defined major system so that during heavy rainstorms, water collects in numerous low spots throughout Mill Woods, thus inundating property and contributing to basement flooding.

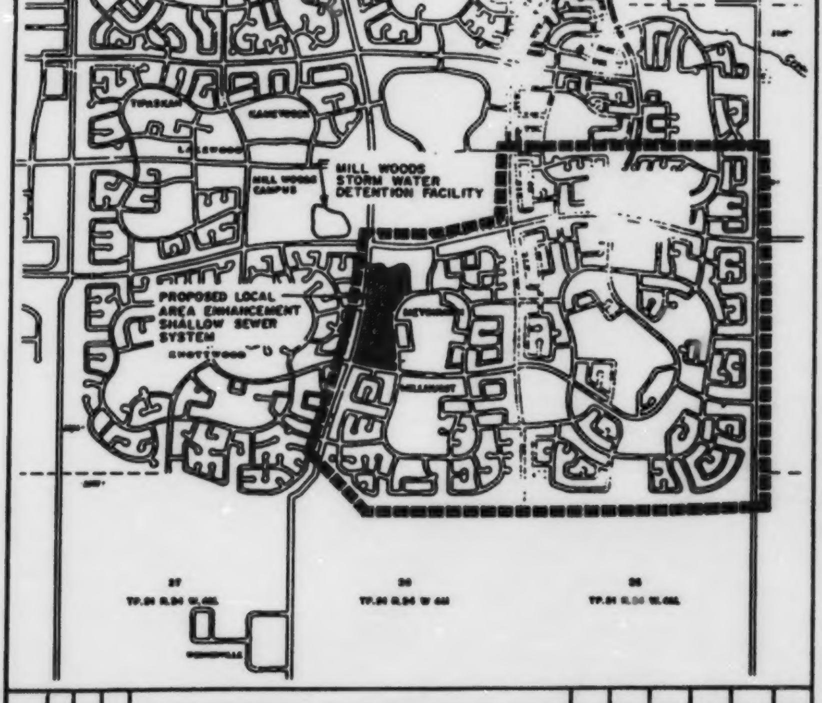
In 1985, a comprehensive relief program covering the whole of the separated sewer area, including Mill Woods, was recommended to city council. This would have provided a 5-year service level at a total cost of $316 million, including $47 million for Mill Woods. However, because of severe fiscal constraints, city council decided to carry out improvements on a staged basis, tackling the worst areas of Mill Woods first.

In June 1986, following this decision, city council approved the report that outlined detailed system enhancements for certain specified areas of Mill Woods. The total cost of this proposal, $11.04 million, was to be spread out over a 4-year period. For administrative convenience, the work was divided into two phases. Phase I combined additional catch basins in the southeast part of Mill Woods, the stormwater management facility, and a shallow sewer system from Meyokumin, just to the southeast of the stormwater pond, to provide that area with a 1-in-100-year major drainage system. Phase II consisted of major drainage systems plus additional storage for two other areas, an underground storage facility and a thorough investigation of inflow and infiltration into the sanitary sewer system.

The work was to be financed on a pay-as-you-go basis from a $1.80/month surcharge on all sewer bills. Although the surcharge was a fiscally sound method of financing, especially in these times of high interest rates and growing debt burdens, the naming of it on the monthly tax notices as "the Mill Woods Sewer Upgrade Program" was a mistake. Not only did it arouse resentment from property owners in other parts of the city who did not feel that they ought to pay to solve Mill Woods problems, but it made it also more difficult to access this source of financing when it became apparent that other areas of the city were in similar need of urgent upgrading work.

Conceptual Design

The major component of Phase I was a stormwater detention facility to be located on the southeast corner of the Mill Woods campus site. This site was the home of two high schools, a cricket pitch, numerous baseball diamonds, soccer and field hockey pitches, and the southwest district offices of the Parks and Recreation Department. It was City land and thus did not have to be purchased. It sat astride the main storm trunk line, which at that point was a 3.8-m oval tunnel. It was close to Meyokumin, an area badly affected by previous storms, and the existing long-term plan for the site showed a recreational "mini-lake" in the same general area. The location plan (Figure 1) shows the area of concern.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MILL WOODS STORM WATER DETENTION FACILITY
MILL WOODS CAMPUS
PROPOSED LOCAL AREA ENHANCEMENT SHALLOW SEWER SYSTEM
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UMA

Edmonton

MILL WOODS DRAINAGE IMPROVEMENTS
MEYOKUMIN AREA

LOCATION PLAN

REV

The design of the pond at this conceptual stage was fairly simple. It envisaged a 600-mm flow restrictor in the existing storm trunk sewer to restrict flow severely, providing spare capacity downstream for other contributing areas and reducing surcharge levels considerably. The overflow of approximately 50,000 m^3 would be stored in a proposed wet pond that could be used for boating in the summer and skating in the winter. The scheme was discussed, in principle only, with representatives of the Parks and Recreation Department, and they raised no objections. The cost of this facility was estimated to be $1.5 million.

OBJECTIVES AND CONSTRAINTS

Stormwater Management Requirements

The objective, from the point of view of stormwater management, was to provide a detention facility to relieve the excess flow in the 3.8-m storm trunk draining the southeast portion of Mill Woods. The general concept was, as stated above, simply to complete an excavation large enough to store the anticipated flow in excess of the 3.8-m trunk sewer capacity.

It soon became apparent that this simple concept was not appropriate for the conflicting demands on the site. The proposed scheme meant that the stormwater retention facility would have been used on numerous occasions each year. This would have led to recurring inflows of first-flush pollutants and frequently varying lake levels. This was obviously incompatible with the recreational functions contemplated for the site. In addition, the depth and surface area required for the calculated storage volume meant that the storm trunk crossed the proposed holding area at a level higher than the floor level of the pond. The first consideration led to the decision to install gates within the line that would close only when the trunk sewer became surcharged (this was modified to closure at 80 percent full - see later). This changed the return frequency for events that would utilize the pond from around once a month to once in 18 months. The second factor led inevitably to a twin-pond configuration: the wet pond on the northern side of the trunk line and a dry pond area on the south side. It was obvious at this point that a large, sophisticated chamber was required to provide the mechanism to operate the system as intended. However, initially the major effort was to finalize a pond design that was acceptable to all interested parties.

Recreation Requirements

As already stated, the Environmental Services Department and the Parks and Recreation Department had agreed at the conceptual stage on the general philosophy that the facility would act as both a utility for stormwater management and a recreational facility. A number of interesting conflicts arose, however, when plans were being finalized.

The original intention was that material from the excavation would be disposed of on the site, spreading it over surrounding areas and reinstating existing facilities at a higher level. However, commitments had been made to recreational groups for the use of the baseball and soccer facilities to the west of the proposed site, and for the cricket facilities to the north. These commitments could not be broken without antagonizing the local community. Delaying the whole project for a full season to allow for construction when the facilities were not in use was obviously not acceptable. Therefore, it became necessary to go to more expensive off-site disposal for all excavated material except for small amounts used for landscaped berms to the east and south. Furthermore, because the campus site is fairly large, it had been assumed that the stormwater facility could encroach onto existing areas which would then be relocated. The City commitments plus the Parks and Recreation Department's understandable reluctance to lose any of the potential for sports facilities afforded by the campuses meant that this proposal was vehemently opposed. These factors essentially defined the boundaries of the stormwater facility. The next problem arose over considerations of the interior content.

The Parks and Recreation Department envisaged very intensive recreational use of the area, including a boat dock, bike paths, extensive lighting, picnic tables and stoves, a large parking area, winter skating, cross-country ski trails and tobogganing, high-density tree planting, and a liberal amount of high-quality landscaping with an artificial stream complete with recirculating pumps. The scale of these proposals were well beyond amenities and landscaping normally associated with such facilities and also well outside the scope of the anticipated budget.

It quickly became apparent in the three-way dialogue (the two departments and the local residents), however, that there was widespread support for these ideas, even though at one meeting someone expressed the view that "he'd swap the lot for some decent tennis courts".

The Parks and Recreation Department solicited input from the adjacent community leagues and held public meetings to make the residents aware of the project.

Public Issues

The flooding issue in the Mill Woods area was well publicized and therefore held considerable public attention with the acceptance of the rehabilitation scheme. The concerns of the public and the politicians focused on three issues:

The Timing for Completion of the Project. The timing of the project was the critical issue and it was this that coloured the approach to the manner in which all the problems associated with the scheme were solved. The proposal was approved in June 1986, and it was essential that the basic stormwater detention facility would be excavated and available to store excess runoff should a major event occur during the summer of 1987. This meant having something in place for the beginning of July, the normal start of the high-risk season. Although 12 months seems to be a reasonable amount of time, on a project as complex as this one, requiring extensive interdepartmental liaison and public input, it meant that many key activities had to be fast-tracked. Any delays raised the spectre of missing important deadlines.

It became obvious toward the end of the preliminary design that there was a lot to be gained and little to be lost by separating out the various aspects of the work and letting them as separate contracts. The earthworks contract, creating a hole for stormwater was the first priority and had to be completed by early summer to provide relief during heavy rainfalls. The landscaping, including the walkways and lighting was timed to follow in the fall. The scheduling of the chamber for winter construction had two advantages. First, it gave time to fully develop the design, including model testing. Second, winter construction lessened the risk of delays from flooding while providing relatively damage-free site access over frozen surfaces.

The three contracts were so diverse that the financial disadvantages of having three separate contracts were most probably negated by ensuring the best price for each aspect of the work.

Minimizing Inconvenience to Residents During Project Completion. The primary interest of the adjacent residents was obviously the flooding relief that the project would provide. However, other concerns had to be addressed as well. Off-site disposal of the material would mean nearly 50,000 truck trips to the disposal site and it was essential that nuisance factors such as noise, spillage of material, and damage to roads should be carefully addressed. Installation of the relief trunk sewers in Meyokumin would mean excavation of existing streets, lanes, and in some cases, boulevards. The public, as always, was apprehensive about the safety aspects of the facility, both during construction and during operation. Above all, the local residents were determined that what was built should enhance the amenities of the neighbourhood and provide a long-term asset. A public relations campaign was initiated to make the residents aware of the various phases of the project.

The Cost of the Project. The preliminary design report showed clearly that the cost of the stormwater facility was, for a number of reasons, much greater than the original estimate. The overall cost of the project escalated primarily as a result of the off-site disposal of excavated material, extensive requirements for retaining walls, and the recreational amenities required. The method of financing initiated considerable political discussion as noted in the Introduction.

In accordance with City of Edmonton procedures, it then became necessary to apply to the executive committee of city council for an adjustment to the capital budget. Although any organization, public or private, dislikes having to admit to conceptual design estimating difficulties, the procedure did have the advantage of focusing everybody's attention on the real cost of combining recreational and stormwater facilities on a single, restricted site. One of the results of the review was to shift the cost of what we have called "additional amenities" from the budget of the Environmental Services Department to that of the Parks and Recreation Department budget (see Tables 1 and 2). This was to cause further problems at the end of the project, as noted in the section entitled "Construction".

DETAILED DESIGN

Stormwater Ponds

The basic configuration of the ponds is shown on Figure 2.

As noted in the previous section, the basic parameters of the detention facility were set down by the restricted nature of the site. This raised some serious problems. In the critical design stages, side slopes of 3:1 and 4:1 were used to form the excavation. They were determined by landscaping considerations raised by the Parks and Recreation Department and had been used on other dry ponds in the city. The City standard for wet

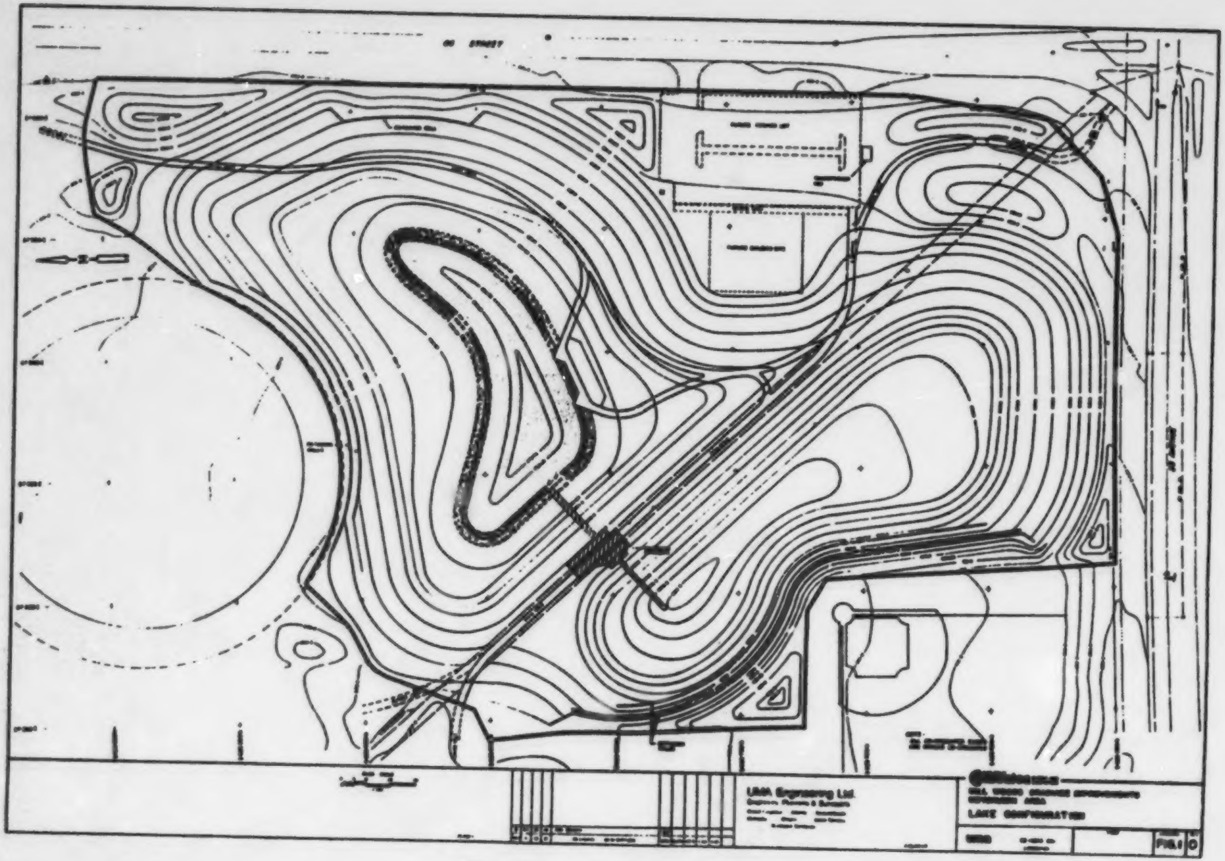
UMA Engineering Ltd.
LAKE CONFIGURATION
FIG. I
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FIGURE 2: Lake Configuration.

Table 1

MILL WOODS STORMWATER DETENTION FACILITY COSTS

BASIC STORMWATER DETENTION FACILITY

EARTHWORKS CONTRACT (Raywalt Construction)		
Earthworks (including transportation of site)	$1,091,000	
Underground Utilities (power, etc.)	255,700	
Extra for Sandstone	79,200	
Landscaping at Burnewood	42,000	
Retaining Walls	141,000	
Relocate District Office	119,400	
Miscellaneous	92,300	$1,820,700
LANDSCAPING CONTRACT (O'Brien Contracting)		
Walkways	$ 61,100	
Trees, Sodding, Seeding, Etc.	149,400	
Electrical	85,400	
Miscellaneous	72,000	$367,900
SITE SERVICES (DISTRICT OFFICES) (Environmental Services)		
Water and Sewer Lines	$71,000	
LANDSCAPING (Parks and Recreation Department)		
Diamond and Cricket Pitch	$25,000	
Temporary Removal of Tress	10,700	
Miscellaneous	5,100	$ 40,800
REGULATING CHAMBER CONSTRUCTION (Pentagon Building - Gate by Eskimo Steel)		
Excavation, Pipework, Etc.	$203,500	
Concrete	399,110	
Gates	118,000	
Miscellaneous	164,800	$885,700
Total Cost of Construction	$3,186,100	
Engineering (Consultants) - Estimate	420,000	
Engineering (In-House) - Estimate	53,000	
Overheads (Administration, Etc.) - 3.68%	132,700	
TOTAL COST OF STORMWATER FACILITY	$ 3,797,800	

ponds was for a maximum slope of 7:1 above and just below normal water line. This is because a 7:1 slope is the maximum slope upon which a person can be guaranteed not to slip and slide down under wet conditions. A similar restraint is exercised by other major municipalities. It soon became apparent to the City and the consultant that in a facility deliberately designed to attract the public, the provision of slope steeper than 7:1, especially below the 1-in-5-year flood level, was difficult to justify. Essentially, a dry pond with water in it is a wet pond. This led to the need to provide extensive retaining walls on the north and west side of the site.

Table 2

MILL WOODS STORMWATER DETENTION FACILITY COSTS

ADDITIONAL AMENITIES

Note: Engineering costs are an estimate as they were included with the engineering costs for shallow sewers, etc. Estimated costs were transferred to Parks and Recreation Budget.

Additional Walkways and Lighting	129,000	
Additional Landscaping	76,000	
Picnic Tables, Stoves, etc.	69,000	
Lakeside Dock and Trailer	91,000	
Intermittent Stream	30,000	
Visitor Parking Lot	135,000	$530,000
Engineering		$ 53,000
Overhead, etc.		20,000
TOTAL COST OF ADDITIONAL AMENITIES		$603,000

Retaining walls were constructed in timber to enhance the site. The height of the walls was kept to 1.0 m to minimize overturning forces and maintain scale. Handrailing on top of the walls ensure safety during normal usage and, more importantly, when the wall is overtopped with stormwater. The walls were tied back into the bank with steel rods to prevent overturning during drawdown. As an additional safety feature, the walls were broken by access steps at 100-m intervals to minimize the possibility of children becoming trapped by rising stormwater. Also landscaping design was such that high points were at the edges rather than at the middle of walls.

During the entire design period, the quality of the water in the permanent wet pond continued to be a concern. The Parks and Recreation Department was adamant that the pond should be suitable for non-contact recreational use during the summer and intended to promote a paddle boat concession. In Edmonton, the use of stormwater lakes for this purpose is discouraged because the relevant Alberta Surface Water Quality Standards cannot be guaranteed at all times. However, in this instance, with the wet pond being off-line, it will be inundated only once or twice a year and should miss the majority of the first-flush pollutants. It was agreed, therefore, that Environmental Services would endeavour to maintain the necessary water quality standards. As a standby, a fire hydrant was installed at the outer edge of the facility above the wet pond and provision was made for a drawdown pumping installation. Should all else fail, the pond can be emptied and refilled with clean water.

Diversion Chamber

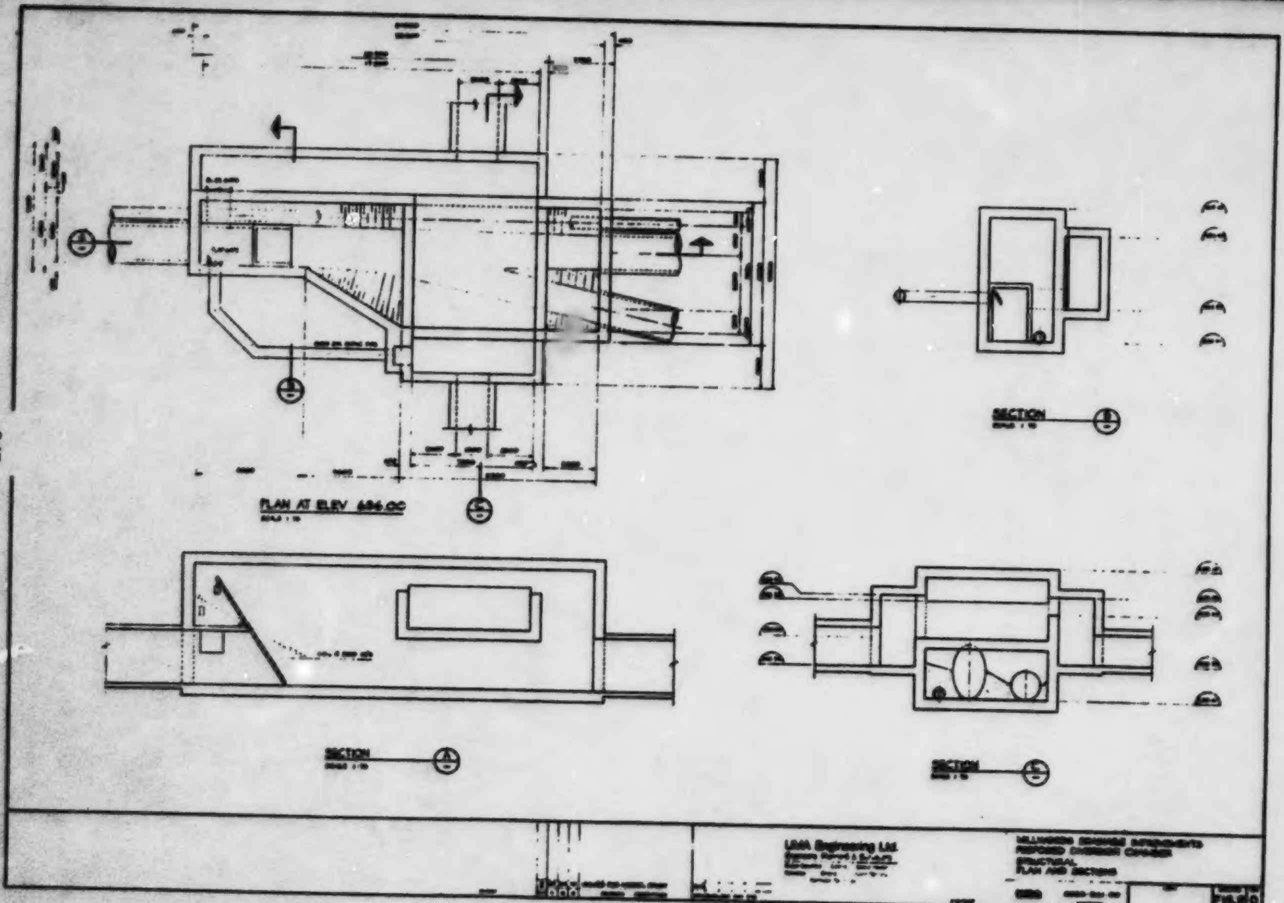
The detailed design of the diversion chamber presented a number of interesting challenges. We were not aware of any completed projects that involve these high flows and constraints that this project did.

The chamber would have to include the following features:

- Provision of a "Y" connection to combine the flow from the 3.8-m storm trunk and a new relief trunk sewer from Meyokumin.
- Maintenance of the normal flow requirements of the 3.8-m storm trunk and the existing sanitary trunk in the same alignment.
- Stoppage and redirection of the flow out of the 3.8-m trunk line into the stormwater lake when the line reached capacity, and then return the line to normal conditions when flows had subsided.

The schematic layout of the chamber is shown in Figure 3.

Our decision was to install a large swing gate above the top elevation of the tunnel gate. The gate would be operated on as simple a basis as possible and with a minimum of dependency on human or electrical devices. The bottom of the gate would be located at a critical elevation so that, when the flow in the line reached that level, the pressure of the stormwater would force the gate closed. The stormwater would then discharge to the stormwater ponds. A piston at the upper end of the gate, combined with its own weight, would return the gate to its normal position as flow in the storm trunk subsided.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UMA Engineering Ltd.
PROPOSED DIVERSION CHAMBER
STRUCTURAL
PLAN AND SECTIONS

FIGURE 3: Details.

The operation of the chamber and the gate were critical to the facility. The firm, Northwest Hydraulic Consultants Ltd., was retained to construct a model to assess the overall performance of the chamber and the operation of the gate, and to determine the maximum discharge that could be allowed through the trunk prior to closing the gate.

The model verified that the original assumptions were correct and detailed design proceeded on the chamber and gates. However, some interesting changes were made following the modelling.

It was apparent following the modelling procedure and more in-depth design considerations, that designing and constructing a gate to achieve the desired results and withstand the tremendous forces would be more complex than originally anticipated. The gate would have to be strong enough to handle the load from the thrust of the full trunk sewer. Therefore, some form of control would be required to prevent the gate from slamming shut when the water forced the gate to close. It was decided to install two gates, rather than one, to reduce the impact downstream, if the gate did not work as intended. Counterweights would be installed to return the gates to their 'open' position when flows subside. Provision would also be included to operate the gates hydraulically from outside the chamber, if they were not operating as intended.

Flow from the chamber to the wet and dry ponds occurs within seconds of the closing of the gates, and the tremendous rush of water to these recreational areas was a major safety concern. Access to the wet pond was considered safer because it would be less likely for people to be in the vicinity of the outlet. (The outlet to the wet pond was designed to restrict access from the public). Therefore the weirs and elevations in the chamber were designed so that the flow would first rush into the wet pond, and then flow into the dry pond area. Special air release chambers would also be required to provide relief for the air being forced down the trunk sewer.

Another major design consideration was to make the huge chamber (approximately 24.0 m long and 6.0 m high) as unobtrusive and aesthetically pleasing as possible. The chamber would be buried for the most part under a berm that covered the trunk sanitary and storm lines bisecting the site. Modifications were made to reduce the height and keep the exposed portion of the chamber to a minimum. The top of the chamber was incorporated into the alignment of the walkway and bike path system through the park. Considerable landscaping and safety features were added to make the facility as compatible with its recreational surroundings as possible.

CONSTRUCTION

Construction proceeded generally as anticipated. Separating the contracts into distinct basic elements (earthworks, diversion chamber, and landscaping) provided the opportunity to meet some of the fast-track schedule considerations.

The earthworks began in the spring of 1987 with completion targeted for the end of June, the traditional start of major rain storms. The program focused on completing the wet pond first to provide the most effective storage in case of a major rain event. (The wisdom of this approach was demonstrated during the "tornado" rainstorm of July 31, 1987, when the excavation was filled with 4 to 5 m of water. Flooding of basements in the area was minimal.) The excavation of the wet pond included "overexcavation" of a porous sandstone at the bottom of the pond and recapping the sandstone with native clay material. The earthworks contract included the construction of retaining walls to maintain slope stability.

The initial landscaping contract began in late summer. The work included sidewalks, park lighting, and extensive landscaping.

The diversion chamber contract commenced in January 1988 and the facility had to be operational for the summer rains. Construction was completed without major climatic interference and was available for the summer rains as required. Construction was also completed on the storm sewers in the Meyokumin area to complete the relief efforts for that area.

Due to other more pressing commitments, the Parks and Recreation Department was unable to start on the second phase of the landscaping work until November 1988, and even then the scope was limited to the construction of the boating dock at the edge of the proposed wet pond. This, unfortunately, has led to the site being subject to a great deal of vandalism over the winter months, uprooting trees, spraying graffiti, attacking control panels, and breaking lights.

CONCLUSIONS

In the retrofitting of existing neighbourhoods to overcome inadequate storm drainage, stormwater detention facilities will play an increasingly important role. In order to gain acceptability and promote the optimal use of scarce land, a combined stormwater/recreational facility makes excellent sense. As this project has shown, however, designers will have to contend with enhanced local expectations, fairly high costs, difficult safety problems, and on most occasions, state-of-the-art technology and fast-track design to provide high-quality solutions within an acceptable time limit.

MANAGEMENT OF URBAN DRAINAGE: CHALLENGES AND TRENDS

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ABSTRACT

Urban centres throughout the Western world are again faced with the task of weighing the acceptable degree of risk versus the affordability of increased levels of drainage service. Environmental concerns that once seemed to have been substantially addressed are back in the limelight. Today, the problem of direct infiltration/inflow (I/I) to sanitary systems is of paramount importance. This paper describes the City of Edmonton's approach to operating, master planning, designing, and upgrading its metropolitan drainage system, a system that is showing the effects of rapid urbanization. The challenge is to identify - taking into consideration the environmental, financial, legal, and political implications - long-lasting solutions acceptable to environmentalists, homeowners, and the sometimes frustrated development industry.

RÉSUMÉ

Les centres urbains des pays occidentaux font de nouveau face à la tâche de mettre en balance le degré de risque acceptable et l'abordabilité d'accroître le niveau de service du réseau de drainage. Les questions environnementales qui jadis semblaient avoir été largement réglées reviennent au premier plan. Aujourd'hui, les infiltrations directes et les afflux dans le égouts séparatifs revêtent un caractère primordial. L'exposé décrit les techniques employées par la Ville d'Edmonton pour dresser un plan directeur, puis concevoir, mettre en service et améliorer son réseau de drainage métropolitain, réseau qui témoigne des effets d'une urbanisation rapide. Le défi consiste à relever, tout en tenant compte des conséquences environnementales, financières, juridiques et politiques, des solutions durables qui rallieront les environnementalistes, les propriétaires-occupants et l'industrie de l'aménagement quelquefois insatisfaite.

INTRODUCTION

In the 1800s, urban drainage design was based on the assumption that approximately half of the precipitation falling on a developed area would find its way to the combined sewerage system. The design also allowed for 1/4 inch of rainfall over a 24-hour period. At that time, the sewage collection system merely dumped the untreated sewage into major watercourses.

Significant advances in environmental cleanup have been made in the 150 years since then. However, there is still gross estuarine and coastal pollution, festooning of riverbanks with sanitary debris, and the destruction of personal property and possessions due to flood waters or sanitary sewer backup. Pollution caused by development outstripping the construction of treatment facilities is well recognized. Prematurely discharging or non-consented overflows on sanitary sewers are also well known. However, the problem of extensive overloading of supposedly separated sanitary systems with groundwater infiltration and direct inflow of surface water from roofs, paved areas, and poorly graded lots has only come to the foreground in the last 15 to 20 years.

As drainage design became more sophisticated and complex, it sometimes seems that environmentalists, engineers, and developers collectively lost their way. After all, how difficult can it be to collect sewage and rainwater, and pipe it away for safe disposal? It appears that by around 1950, policy makers and developers felt that they could provide a cheaper job by "innovative design". Designers began to acquire powerful computer programs to simulate the effects of storms on a dynamic basis, replacing the traditional methods that considered the complex networks on a static basis only.

From the mid-1970s to early 1980s, many municipalities became aware that excessive direct inflows were seriously overloading the public drainage systems. We must now go back to basics. The output of a design is only as good as the input, and assumptions we have made about our drainage systems have misled us.

DEVELOPMENT AND SERVICING

Overview of Edmonton's Drainage Facilities

Typical of a prairie city, Edmonton is extremely flat, and this poses particularly onerous challenges to a drainage engineer. At present, there are more than 4,500 km of storm and sanitary sewers, 60 pumping stations, 100,000 manholes and catchbasins, and 32 stormwater management lakes and dry ponds. Sewers range in size from 8 inches to 17 feet in diameter and depths range from 8 to 200 feet. Annual expenditures on new upgrades and relief sewer systems are in the order of $30 million and the annual operating budget is approximately $30 million. To operate and maintain the drainage collection and treatment facilities requires 320 employees.

Since the turn of the century, Edmonton's population has increased more than 200-fold, the majority of that increase occurred from 1950 to 1982. the average daily water consumption increased from 56 ML in 1952 to 326 ML in 1987. Similarly, flows arriving at the Gold Bar Waste Water Treatment Plant increased by 50 percent during the 1970s, from 186 ML/d in 1972 to 273 ML/d in 1980 with a gradual decrease to 236 ML/d in 1987 when the recessionary period began. The current treatment standard at Gold Bar is 25 mg/L for both suspended solids and biochemical oxygen demand, a standard that is achieved 100 percent of the time. Edmonton's rainfall is in the order of 17 inches. Approximately 25 percent of the drainage system is combined.

Effects of Rapid Urbanization

The most recent period of urbanization began in the mid-1970s and caused the following significant changes:

- The standard of living increased tremendously and the public expected higher levels of municipal services. Several years ago, homeowners experiencing flooded basements would consider it normal that they clean up the mess themselves. Nowadays, in the majority of the cases the City is expected to clean it up immediately.

- We have become an information society with increased reporting of events, a greater awareness of problems, and more demands for instant actions.
- Effluent standards for our wastewater treatment plants have dramatically increased. We have progressed to the point that we now recognize that even stormwater is not necessarily clean and its run-off may have a deleterious effect on the receiving watercourse.
- Our water treatment process has been expanded and modernized to keep abreast of modern technology, although Edmonton still has 80 storm sewer outfalls that discharge upstream of the intake to the downtown Rossdale Water Treatment Plant.
- Just recently, we have located a site for a new sanitary landfill to accommodate our ever-increasing volumes of garbage. Nevertheless, the disposal of sewage sludge in an economically acceptable manner poses a major problem.
- We have built much larger homes on significantly smaller lots, thereby dramatically increasing the area of paved and covered surfaces which, in turn, requires larger sewers to covey the rapidly generated flows away at a much faster rate than previously.
- Design standards have been changed in the past two decades in response to presssures from the development industry, as well as to conform to the general trends and practices in drainage engineering. Today, we recognize that previous design standards were inadequate for the physical system we now have and that the service requirements and expectations of the user/homeowner have not always been met.

The short-term economies and the industry's compromises could be accommodated until development ultimately caught up with the initial design numbers of when exceptionally heavy rainstorms occurred.

During particularly intensive periods of development, not enough people were available to enforce servicing standards. Of particular concern is the outstanding number of incorrect house connections where storm pipes were connected to sanitary sewers and vice versa. Apart from the direct pollution of cross-connections, it is estimated that one wrongly connected downspout generates a flow equivalent to about 30 properly connected houses; and on average, for each badly graded lot, excessive weeping tile flows are such that this condition is equivalent to the development industry losing 20 potential lots.

Consequences of Heavy Rainfall Events

Because of the effects of heavy rainfall events in recent years, the City of Edmonton has formed a task force to address concerns of the public and the development industry regarding the adequacy of the metropolitan drainage system. In 1978, 134 mm of rain fell in a 24-hour period causing flooding in 1,500 basements, mainly in the southeast part of the city. Ten years later in July of 1988, a long-duration storm with approximately 100 mm of precipitation followed several days of low-intensity rainfall. This caused 1,200 flooded basements throughout the city, but most were in the northeast area where the storm was concentrated. Basement flooding was caused both by sanitary sewer backup and by seepage of rainwater through the basement structures.

The July 1988 storm led to a great deal of concern about the adequacy of the relatively shallow trunk systems serving the northeast area of the city. The wisdom of allowing further development to take place in the areas upstream of existing development was especially questioned. Consequently, the sanitary basin boundary line was re-established at the limit of existing development.

The location of the "red-line" was based on the incidence of basement flooding in the areas downstream. It is the Environmental Services Department's position that, in light of this flooding, an especially cautious approach must be taken with all new developments. We must be certain that we do not aggravate the situation for existing homeowners. In the majority of cases, the recipient of the sewage in a flooded basement caused by sanitary sewer backup is not the generator. We must also protect the City from lawsuits. The hottest issue today is the restriction placed on a number of proposed developments built on the wrong side of the red-line. There is a great number of aldermanic enquiries regarding concerns about the development industry.

Causes of Sanitary Sewer System Overloading

The cause of overloading is infiltration/inflow (I/I), in engineering terms referred to as stormwater (or direct) inflow and rain-responsive infiltration.

The simplified hydrograph in Figure 1 shows flow on the vertical axis and a time period slightly in excess of 24 hours on the horizontal axis. The shaded area #3 depicts the variation in normal sanitary decline during the day, and a second peak at 6 pm when most people return from work. At night, there is a sharp drop off in flow; and in the early morning hours there is a very minimal flow. At the bottom of the graph, area #1, there is the base infiltration which remains virtually constant. Area #2 represents rain-responsive infiltration, which increases just after a period of rainfall. Direct inflow, shown as horizontal shading (area #4), increases immediately very sharply after rainfall.

Some Definitions

Base infiltration is the portion of infiltration that varies with seasonal movements of the groundwater table. Entry to the sewer is through cracked pipes, manholes, and bad joints in the pipework which allow seepage of natural groundwater and leakage from watermains.

Rain-responsive infiltration is typical for areas with poor natural drainage and is characterized by a lengthy decay period.

Direct inflow enters the system very quickly via direct connections such as rainwater entering the weeping tile from (see Figure 2):

- roof leaders spilling in the backfilled areas around foundations,
- lot grading sloping toward the house, and
- window wells receiving overland flow.

In addition, inflow can enter the sanitary system via vent holes in the manhole covers and around the rim when street- or land-ponding occurs.

SANITARY SYSTEM OVERLOADING

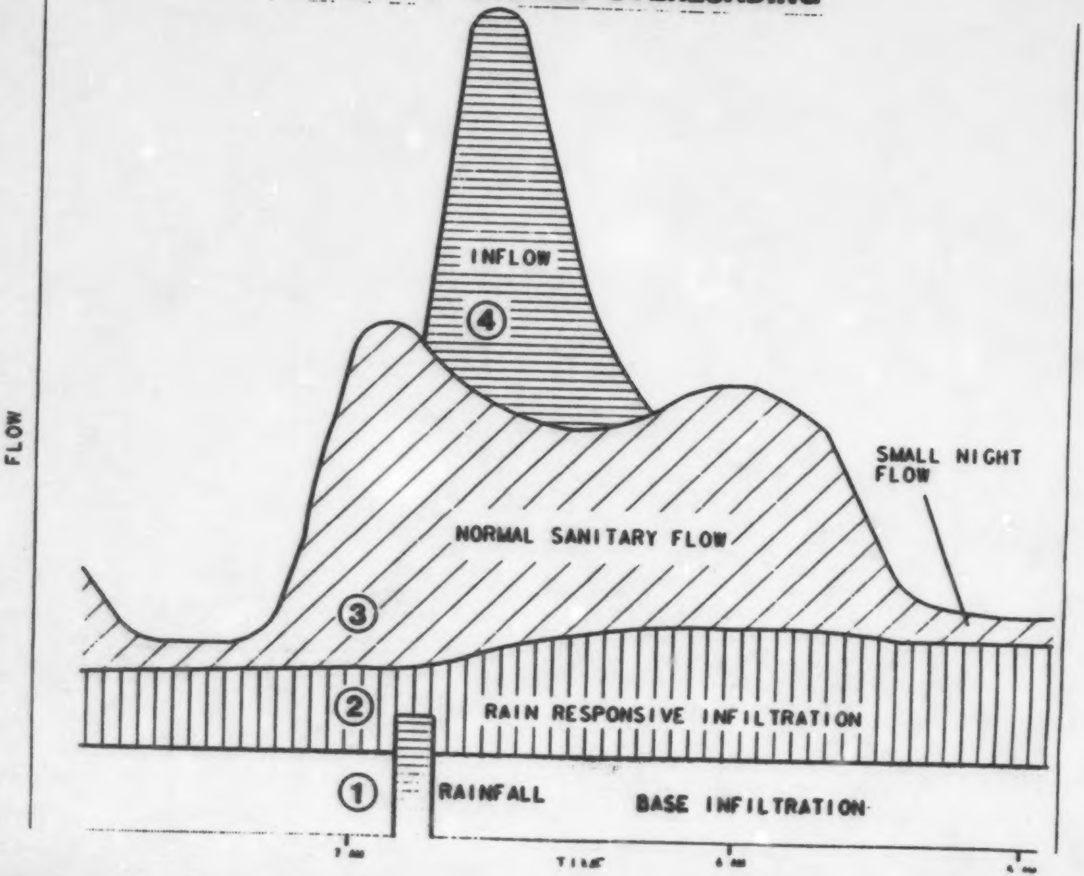
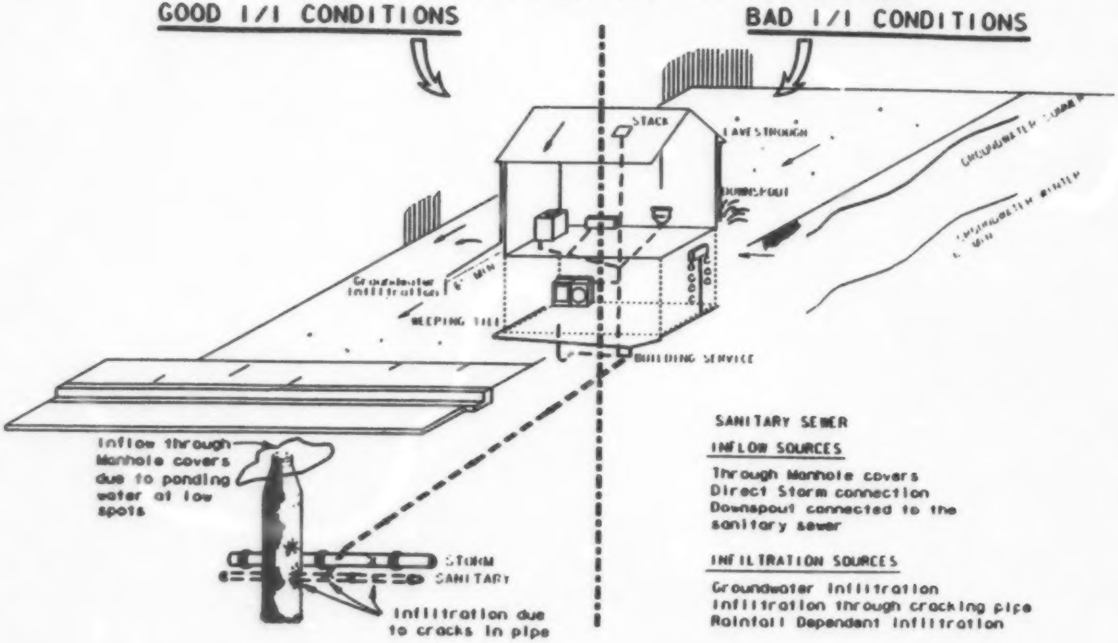

INFLOW
④
NORMAL SANITARY FLOW
SMALL NIGHT FLOW
③
②
RAIN RESPONSIVE INFILTRATION
①
RAINFALL
BASE INFILTRATION
FLOW
7 am
TIME
6 pm
6 am

Fig. 1

SANITARY SYSTEM OVERLOADING

SOURCES OF INFLOW AND INFILTRATION


GOOD I/I CONDITIONS
BAD I/I CONDITIONS
STACK
EAVESTROUGH
DOWNSPOUT
GROUNDWATER SUMMER
GROUNDWATER WINTER
6' MIN
Groundwater Infiltration
WEEPING TILE
BUILDING SERVICE
Inflow through Manhole covers due to ponding water at low spots
STORM
SANITARY
Infiltration due to cracks in pipe

SANITARY SEWER

INFLOW SOURCES

Through Manhole covers
Direct Storm connection
Downspout connected to the sanitary sewer

INFILTRATION SOURCES

Groundwater Infiltration
Infiltration through cracking pipe
Rainfall Dependent Infiltration

Fig. 2

It is critical to recognize that the sanitary system in separated areas is intended not to flood. Its response should not be rain-related and would not normally be described as having a service level with a 1-in-5-year or 1-in-50-year flooding frequency, as may now be the case.

Impact of Servicing Strategies

Separated systems were brought into being because of:

- failure of the combined systems, i.e., overloading of the sewers during heavy rainfall;
- environmental concerns about discharges of raw sewage to water courses via the combined-sewer overflows; and
- efforts to reduce treatment plant costs caused by the high volumes of stormwater received at the plants.

History of Drainage Servicing in Edmonton

Pre-1948. There was combined-sewer servicing with sewers taking sanitary flows only through single-pipe servicing. No weeping tile was used and roof leaders were installed to drain out onto grassed areas.

1948-1958. Combined sewer-servicing took both storm and sanitary flows through a single pipe from each house. Weeping tile connected to the sewer service was introduced in the latter years. Many of those areas now have roof leader disconnection programs underway; e.g., Parkallen, Rossdale, and Cloverdale areas.

Early 1950-1970. Separate storm and sanitary sewers were introduced. Residences were serviced with two pipes, storm to the front and sanitary to the rear of the house. Roof leaders were connected directly to the storm service pipe. Weeping tiles were connected to the sanitary service pipe. This overall system completely separated all flows from residences, minimizing the possibility of flows entering the wrong pipe.

1970-1980. During this period, it was decided to place both the storm and sanitary sewer systems together in a common trench concept. This reduced servicing costs substantially, both on and off private properties. The common trench concept led to the first of the I/I problems, the cross-connecting of sewers: storm to sanitary and sanitary to storm.

Because of the cross-connection problems, yet another approach to servicing was initiated in the late 1970s. This used a portion of each of the previous ideas. The developments are still serviced by common-trench storm and sanitary mainline sewers, but the individual lot is serviced with a single sanitary sewer service pipe. All sources of wastewater and the weeping tile are connected to this pipe. The roof leaders discharge through leader extensions onto the owner's property for the flows to be directed overland to street catchbasins or absorbed into the soil.

Unfortunately, many of the roof leader extensions from the buildings are either non-existent or in inoperable positions. When this occurs, storm runoff is discharged within 12 inches of the foundation wall. As the flow accumulates, it becomes a direct source of inflow to the weeping tile and consequently to the sanitary system.

Herein lies the problem of uncontrollable inflows to the sanitary system for which the system was not designed. The Drainage Engineering Section has opposed this method of servicing. The directive to accept this came from the now defunct Commission Board in response to pressures from the development industry.

1988. It is now required that the weeping tile discharge to a sump which, in turn, is pumped out by an electric sump pump for discharge across the owner's private property.

KEY ISSUES

In summary, some of the key technical tasks being addressed in Edmonton are:

- the magnitude (duration and intensity) of the design storm and degree of risk vis-a-vis the affordability of an acceptable level of servicing standards;
- reduction of volumes of I/I at the source, wherever practical;
- renewal and maintenance of the integrity and isolation of the separated sanitary systems;
- recognition of the need to accommodate stormwater from:

-lengthy periods of precipitation, and

-the "flash" runoff from short-duration storms that has more recently been the basis of designs;

- recognition of the need to exceed the established minimum design standards, and further, to incorporate a safety factor if we are to truly protect homeowners from flooding; and
- ensuring thorough inspection of sanitary, storm, and weeping tile installations for every new home constructed, together with a continuing program to ensure proper lot-grading. Perhaps the industry could introduce strict controls on our drainage appurtenances such as those enforced for the power and gas industries.

Tackling these issues would define target levels of service and have a significant impact on future capital works planning and priorities. In addition, it may provide answers for frustrated developers in parts of the city. It is noteworthy that numerous municipalities are grappling with similar issues. In the view of many developers, the most cost-effective solution to the I/I problem is to introduce city-wide legislation to have all homeowners rectify any defective lot-grading. Though this may appear attractive in simple financial terms, it is doubtful that this would be a politically acceptable solution. The financial arrangements for "front-ending" the oversizing of trunk lines for anticipated future developments must be resolved. Is the developer or municipality to pay initially? If it is to be the municipality, should the cost be spread out across the entire tax-paying population or be absorbed just by the new home-buyer?

EDMONTON DRAINAGE TASK FORCE

The Drainage Task Force was established in the fall of 1988 to address public and political concerns, and those of the development industry about the adequacy of the metropolitan drainage system. The work consists of a comprehensive review and evaluation of industry standards and the performance of the City's systems. It culminates in the compilation of remedial action plans and a long-term master plan to meet the expectations of the public and city council. The tasks fall into four main categories.

Master Drainage Plan

The Master Drainage Plan is being prepared by in-house staff and the first draft will be completed by early March. The plan will be issued in four volumes:

1. Storm Collection System
2. Sanitary Collection System
3. Pumping
4. Wastewater Treatment Plant

The drafts will be reviewed by two different consulting companies and modified as necessary before presentation to city council.

Review of Servicing Standards

The city-wide review of servicing standards is being carried out by CH2M HILL Engineering Ltd. This review is examining the adequacy of our sanitary and storm standards. Water quality and regulatory aspects are also being studied, and comparisons are being made with other Canadian and U.S. cities. The municipalities include Scarborough, Mississauga, Laval, Ottawa, Winnipeg, Regina, Calgary, Chicago, and Milwaukee. Alternative levels of service, cost implications, and new development control procedures will be reported by May 1989.

Localized Northeast Study

A second consultant is examining in detail the drainage problems in the northeast area of Edmonton. The sanitary system is being analyzed using the appropriate I/I inputs for each type of differently serviced area. Computer simulation runs have been completed and alternative relief options are now being formulated for various development scenarios. The study will be completed during February and its findings reported to the utilities and finance committee in early March, at which time the various options with cost estimates and possible implementation schedules as well as degrees of benefit and risk will be made available.

The northeast study includes a hydrogeological assessment. This involves the installation and monitoring of 29 permanent standpipes as well as a review of data from several pre-existing geological reports. The assessment indicates that, contrary to speculation, there is no significant effect of groundwater infiltration on the existing sewer system of foundation weeping tiles.

The study also includes a flow monitoring investigation that has revealed that, even during dry weather flow, there is a flow of 2 ft^3/s greater than expected in one of the five 15-inch (diameter) sanitary trunk sewers. This line runs through a recently flooded area and, if it is connected to a rain-dependent source, serious overloading during rainfall can be expected. Attempts are being made to discover and eliminate the source of this extraneous flow.

Social Impact Study

A social impact study is being conducted by a third consultant who is seeking public input of preferred levels of service and the affordability of each. The public has been advised of the work of the Drainage Task Force through newspaper advertising before Christmas and through a recent publication called "Follow the Flow." Meetings with the public are being held as well.

During the period of March to May 1989, a "Public Issues Feedback Report" will be considered and revisions made to the draft Master Drainage Plan. By August, additional meetings with the three stakeholder groups will have been held before preparation of a final "Public Issues Feedback Report" to comment on how concerns, issues, and options are addressed in the final draft of the Master Drainage Plan.

Review Committees

Two review committees are examining each of the two engineering studies, servicing standards review and northeast drainage problems.

The role of the review committees is to bring to the consultants' attention the concerns of all parties involved in the flooding issues. The committees are reviewing project progress at the milestone stages, and commenting on the conclusions and recommendations of the consultants. It is the consultants' responsibility to recognize the concerns brought forward by the committees and to consider them in drawing conclusions and making recommendations. The review committees are made up of representatives from expert and interested parties.

The review committees and the social impact study are examples of in-depth public participation in the decision-making process that must relate public affordability to desirable levels of drainage servicing.

PLANNING AND DESIGN

Demographics and Expectations

Urbanization in the last 20 years has resulted in major shifts in the demographics of the Canadian population. In what was formerly a nation with a large rural population, fully 75 percent of the people now live in cities and towns. This trend is likely to continue. Practically all immigrants settle in larger urban centres and the rationalization and globalization of the agricultural sector will result in fewer people being employed in this industry.

Because of the oil industry boom in the 1970s, Alberta experienced a growth rate unrivalled by any other province in Canada during this time. Energy-related developments increased the demand for workers, and people flocked from other areas of Canada to settle in Edmonton, Calgary, and other urban centres. Government and service industries grew apace.

How do we manage and control this growth in our urban centres without excessive strain on the existing infrastructure? How do we provide a level of service consistent with the expectations of the modern city-dweller? That is the challenge facing urban planners, engineers, and the development industry today.

Urban drainage systems, which in the context of this paper cover the collection systems used to effectively bring sanitary flows and stormwater to convenient locations for treatment or disposal, or both, form only a part of the total urban infrastructure. However, the performance of the drainage systems during heavy rainstorms in recent years has underlined serious deficiencies. The flooding statistics of some of the major Canadian municipalities (see Table 1) give some indication of how serious the problem is.

Design Challenges and Trends

When drawing up plans for urban drainage systems, several design objectives have to be met.

Facilitate Orderly Development in Accordance with the Master Plan or City Plan. This plan, which addresses all aspects of the physical development of a community, is the most central and important document for the management and control of a community's growth and development.

Minimize the Adverse Environmental Impacts of Development. Erosion, sediment deposition, and flooding.

Minimize Ponding, Flooding, Property Damage, and Health Hazards. Note the use of "minimize" as opposed to "prevent", a word which the public and politicians would sometimes prefer to use. However, all parties have to realize that eliminating the risks of flooding, etc., is not possible in most cases.

Prevent Loss of Life. There have been fatalities during recent rainstorms in western Canada. It behooves design engineers to examine the causes of these deaths carefully and incorporate appropriate design measures into drainage systems to prevent such occurrences.

Table 1

Basement Floodings in Various Canadian Municipalities

Location	Event	Estimated Number of Flooded Basements	Comments
Edmonton	88/07/06	1,200[1]	Long-duration storm (24 hours
Edmonton	87/07/31	340[1]	Tornado event; concentrated on small area
Calgary	88/08/25	1,500[2]	Short-duration storm (30-45 minutes)
Regina	83/08/15	9,000	Estimated 1:100 event (3" in 3 hours)
Winnipeg	84/06/20	17,000[3]	Includes even minor flood damage. Figure significantly reduced after submission of claims.
Ottawa-Carleton	86/09/	300[1]	3-4 hour storm
Laval	87/07/14	1,000[1]	

[1] Based on Residents' complaint calls

[2] Estimate based on flood levels on streets

[3] Based on extensive phone survey by City

As with all procedures and systems designed by human beings, the objectives have to be balanced against the inevitable constraints. In urban drainage the constraints can be:

Regulatory (at a local, provincial, or federal level)

Physical (It may be physically impossible to control flooding, so it becomes necessary to delineate a flood plain.)

Social and Institutional

Economic and Financial (Conditions may be such that development to a required level of service is not economically feasible.)

The objective/constraint balance may appear to be a motherhood statement. It is, however, useful to place urban drainage in perspective within the full development process. Urban drainage along with water supply, treatment, and distribution, transportation system planning, and solid waste collection is one of the major engineered components of urban planning and development.

The importance of urban drainage on the Canadian prairies is accentuated by the topography. Most people flying into Winnipeg or Edmonton will be struck by the flatness of the urban expanse. An urban drainage engineer will ask, "How do you drain such an area?" Frequent pumping stations within the sanitary collection system (a total of more than 60 in the City of Edmonton's system) have become necessary. Stormwater management lakes have become an indispensable feature of urban drainage system design in cities such as Winnipeg and Edmonton.

The following paragraphs describe the main challenges facing urban drainage system designers. Brief comments are also provided on how these challenges are being addressed and how the related problems are being solved. Each component of urban drainage could be the subject of a technical presentation. In keeping with the general nature of this paper, we only discuss each briefly.

Level of Service

It is now generally acknowledged as a principle of drainage engineering (and drainage law) that urban drainage systems are not designed for the extraordinary event.

This fact, however, does not absolve us as engineers from the responsibility of determining and defining an appropriate and dependable level of service, and explaining its implications to the public and to politicians. The concepts of recurrence intervals and a 1-in-5-year or 1-in-50-year storm are concepts not easily explained to the layman.

The challenges can be even greater in older urban areas with their combined sewer systems that, in addition to being underdesigned to begin with, have undergone serious deterioration with age. All major cities in North America are faced with rehabilitation of their aging drainage systems. Table 2 provides an indication of the levels of expenditure required.

Table 2

Drainage System Upgrading: Rehabilitation Costs

Location	Population	Cost for Rehabilitation ($ x 10^6)	Program Comments
Winnipeg	600,000	$ 325	$200 million spent; $125 million proposed (15-year program) for basement relief only
Boston	2,000,000	$ 2,000	Combined-sewer overflow facilities only
Milwaukee	1,700,000	$ 2,000	Includes sewer system and treatment facilities, rehabilitation, and upgrading
Chicago	6,000,000	$13,000	TARP (overflow storage only) costs; does not include treatment facilities

The definition of level of service became a major issue in a recent sewer rehabilitation program for the Lago-Lindo and Dunluce/Warwick subdivisions in Edmonton. The residents had difficulty understanding why the sanitary sewer system was backing up and flooding basements. The City and the consultant had monthly meetings with community liaison committees at which all components of the rehabilitation schemes were discussed. Levels of service based on storms corresponding to increasing return periods were evaluated and rehabilitation costs prepared. The residents accepted and understood the relationship between cost and level of service.

They agreed with the engineers' recommendation, though it meant that their homes were not safe against an infrequent major storm event (greater than a 1-in-50-year storm) (Reference 1).

Probability and Design Storms

Storms used as a basis for system analysis and design are usually probability-based. Questions that need to be answered are:

- How adequate are data on which design storms are based? Are we using just 10 years of data to extrapolate to a 100-year storm? If the sample is too small, the probabilities derived are unlikely to be reliable.
- How relevant are the data being used? The observed data should be consistent with the phenomenon being studied, be it peak flows, duration, or volumes.
- Are the data accurate and homogeneous?
- What is the basis of the IDF curves being used? Are we blindly using IDF curves developed decades ago by a defunct agency? Does the determination of extreme values take into account recent events?

If the data used to calculate the design basis were not the most relevant available, the courts may hold a municipality or an engineer liable (in negligence) when an underestimated design storm causes damages during a subsequent event.

No longer is it sufficient to design an urban system for just one storm. It is becoming necessary to determine the response of the system to a range of storms in order to fully understand its behaviour. With the proliferation of storage facilities, at least two design storms - a short-duration event to determine peaks and a long-duration event to assess quantities - should be used in the analysis.

System Analysis

System analysis by computer is a necessary feature of modern urban system design. However, caution must be exercised when using sophisticated models to calculate the responses of the system to storm and other inputs. Firstly, the interpretation of results of model analysis calls for experience in the hydraulic behaviour of the collection facilities. Too often results are accepted and presented by computer modellers without critical review by design and operations engineers who have more knowledge regarding how the systems should and do operate. Also, the availability of different computer models, including many that are microcomputer-based, has grown. These models have various features that may or may not be suitable for analysis off the existing or planned system, i.e., analysis of a sanitary sewer system (with or without I/I) may call for a different set of features than, say, a storm sewer or combined system.

CH2M HILL recently carried out a study to assess the available analytical models and identify the most suitable for the sanitary sewer system of a medium-sized city. Model features, listed in Table 3, were categorized as follows:

Essential:	a feature critical to the future use of the model
Necessary:	a critical feature that can be achieved through independent modules developed after setups
Desirable:	a useful feature but not critical to applying the model

A total of 56 available and potentially available models were identified. All were assessed against the essential, necessary, and desirable features listed and a shortlist of six was prepared. In this case, which may not be representative of many municipalities because of system and other differences, the models shortlisted for a further, more detailed assessment are shown in Table 4.

Development of Design Criteria

The sophistication of the methods used to analyze urban drainage systems has to be matched with a commensurate improvement in the accuracy and applicability of input data. This provides the municipalities with the challenge of having available realistic field data for calibration, verifying of the analytical models, and establishing effective design criteria for development for urban expansion.

Allowances for I/I have traditionally been based on textbook figures with little or no consideration given to the particular features of the developed area. In the course of the last 10 years, the City of Winnipeg has carried out extensive tests on on-lot drainage and weeping tile flows. The results have indicated the impact of weeping tile response to rainfall on deficiently graded lots. The City of Edmonton, currently assessing its

Table 3

Sewer Model Features

Feature	Priority	Comment
Runs on available hardware	Essential	
Common, high level language	Essential	Essential for modifications
Dynamic hydraulic routing	Essential	Flows vary with time
Model surcharging	Essential	System surcharges
Allows weir/diversion input	Essential	System has diversions
Source code available	Essential	Essential to modifications
Expandable for growing system	Essential	
Models all or part of system	Essential	
Has vendor technical support	Necessary	
Variable speed pump stations	Necessary	If units used in system
Constant speed pump stations	Necessary	If units used in system
Does weir/diversion hydraulics	Necessary	
Models off-line storage	Necessary	
Models wetwell surcharge	Necessary	Wetwell can surcharge pipes
Well documented	Necessary	Documentation could be improved
Compatible with existing databases	Necessary	
Reasonable purchase cost	Necessary	
Hydrograph adjustment factors	Necessary	
Generates sewage flow	Necessary	
Generates I/I flow	Necessary	
"n" from materials and age	Necessary	
Reports full pipe capacity	Necessary	
Combines hydrographs	Necessary	
Accepts alphanumeric manholes	Necessary	
Models "slug" flows	Desirable	
Allows controlled diversions	Desirable	Potential feature of future system
Computer efficient	Desirable	
Models H_2S and DO w/treatment	Desirable	
Evaluates pipe corrosion	Desirable	
Models conservative substances	Desirable	
Estimates repair/replace costs	Desirable	
Calculates inverts from slope	Desirable	
Has network graphics	Desirable	
Has profile graphics	Desirable	

standards for eventual upgrading, has studied pipe flow variation based on different standards. For a typical subdivision with a population of 1,000 people, the sanitary sewer flow based on normal dry-weather flow pulls allowances for groundwater infiltration and weeping tile response to a 1-in-25-year storm is estimated at 0.11 m^3/s. Calculation of the design flow, based on the City of Edmonton 1978 design criteria, yields a flowrate of 0.01 m^3/s; i.e., a tenfold difference. There is no doubt that extraneous flows into the sanitary drainage systems have been significantly underestimated. The design challenge is to come up with realistic standards so that our analyses represent the real world.

Table 4
Sewer Analysis Models

Model	Comments
HVM	Developed in Germany; extensive use in Europe and Toronto; suited to evaluation of complex systems
DWOPR	Developed by National Weather Service; uses full form of hydrodynamic equations.
SAM	Developed by CH2M HILL; uses kinematic flow routing; provides hydraulic grade line.
SOGREAH/CAREDAS	Developed in France; extensive use in Europe; complex system evaluation
SWMM w/EXTRAN	Transport block of SWMM widely used; EXTRAN has all essential features except expandability.

Reduction of I/I

During wet weather, wastewater flows throughout our collection systems and treatment plants regularly exceed average dry-weather flows by a factor of 3 or 4, sometimes peaking at more than 10 times the dry-weather peaks. The necessity of reducing I/I into sanitary sewer systems cannot be overemphasized. I/I is causing extensive flooding, and the costs to convey and treat the peak flows are extremely high. I/I reduction methods being implemented in the City of Edmonton are:

- downspout correction and lot-regrading programs,
- disconnection of weeping tile from the sanitary sewer,
- plugging and sealing of manhole covers, and
- identification of cross-connections and illegal service connections by smoke testing, dye testing, and video examination.

Increased emphasis is now being placed on I/I reduction when planning for new or expanded treatment facilities. In many cases, high capital expenditures on these plants can be eliminated or postponed by an effective I/I reduction program. In the U.S., the EPA now requires that an I/I study be carried out before funding is approved for expansion or construction of treatment plants.

Total elimination of I/I is a pipe dream and this should be acknowledged by designers of new systems. There is, however, an optimum level of reduction that provides the greatest benefit for the least cost. All municipalities should be aiming for this optimum.

Combined-Sewer Overflows

Each major North-American urban centre has had a combined sewer system and most are currently grappling with the impact of bypassing, without treatment, wet-weather flows above the capacity of the collection or treatment facilities. There will be increased pressure from regulatory bodies (and legislation) to reduce the frequency of (or eliminate) combined-sewer overflow (CSO) or provide appropriate treatment of some wet-weather discharges.

Efforts by municipalities to cope with their CSO problems have given rise to some innovative measures to avoid the costs involved in increasing the capacities of both conveyance and treatment facilities. Among these are:

- provision of storage basins (off-line storage) to equalize flows,
- development of operational controls (weirs, gates, diversions) to fill available sewer lines (inline storage) prior to overflow, and

- use of real-time models to predict future flows from current weather or current upstream flows, and operation of the system in preparation for anticipated wet weather conditions.

Several municipalities are now researching this predictive operational control strategy. The City of Seattle pioneered the use of system-wide computer control of its collection system for the real-time operation of in-line storage facilities in its combined sewers. The installed system has been credited with reducing the volume and frequency of overflows.

The City of Milwaukee has a centralized collection, the first use of predictive operational control in a separate sanitary system. The objective of this measure is to maximize retention of flows and minimize the discharge of pollutants by operating the system to fully use the existing capacity for conveyance, storage, and treatment prior to bypassing. Any overflows that occur after the full use of in- and off-line storage will be dilute because they will occur only during major storms and after the concentrated "first flush" has been retained.

Public Participation and Information

More questions are asked by people and more details are sought on day-to-day issues that affect the public directly and indirectly. This places a great challenge on municipal governments to make sure that every citizen is treated equally and that each is kept informed and updated on matters that are of interest to them. This leads to a trend of more uniform standards in the management of urban drainage systems and will encourage a greater exchange of information between municipalities regarding drainage systems. It is anticipated that provincial engineering associations will play a major role in this matter. One of the trends that will come out of this growing demand for information is that municipal governments will put more effort into public relations and education.

Performance Comparisons

How are Canadian municipalities meeting the challenges associated with the design of efficient urban drainage systems? Because of the diversity in drainage environments, approaches to maintenance and financing, and government jurisdictions, a quantitative comparison is difficult.

Edmonton's Drainage Task Force is making comparisons with other North American urban centres on the basis of:

- background information
    - size and population
    - type(s) of flooding
    - annual new development rate
    - role of city in design and construction
    - municipal jurisdiction

- sanitary and storm servicing
    - design objectives or goals
    - design standards, policies, and procedures
    - construction controls and acceptance procedures
    - buildings bylaws and controls

- planning and development control procedures
    - land-use planning process
    - subdivision development

- financing
    - means employed to finance storm and sanitary facilities
    - subsidies

- administrative structure and department relationship
    - storm and sanitary sewer design and construction

- legal aspects
    - bylaws
    - liability in regard to surface and basement flooding

Some Frequent Problems. A recent survey of stormwater management practices in the U.S. (Reference 2) provided some interesting results. Among the problems most frequently identified were:

- Designers and administrators are often intimated by the complexities of system modelling, statistical probabilities, and other technical jargon.

- Drainage is often seen as a low-priority item compared to roads and sanitation.

- There is little knowledge of the state of repair of drainage infrastructure, which makes ongoing maintenance impossible to schedule or budget.

- Master plans, if available, are cumbersome to interpret or they use advanced computer analysis that is beyond the capability of engineering staff to easily modify and reuse.

- A comprehensive planning and policy document, backed by effective ordinances and enforcement powers, rarely exists.

- There is a lack of usable data, allowing design engineers to use inferior methods.

- Day-to-day maintenance is driven by complaints and political pressures, resulting in a dearth of preventive maintenance activity.

Characteristics of Successful Programs. More interesting, perhaps, is what were found to be the characteristics of successful programs identified in the same survey.

Problems Identified and Solutions Found. Municipalities with successful programs appeared, without exception, to have committed adequate resources at the outset to identify and quantify the problems, formulate options for problem resolution, and focus on the chosen solutions. Most of them had gone on to develop a coordinated program that took advantage of the unique physical and political environments in which they functioned.

Development Tightly Controlled. Development was controlled, not in the sense of restricting development, but in ensuring that it bore the full cost of system expansion. Each successful program had well developed procedures to control development, detailed submittal requirements, adequate inspection staffs, and streamlined enforcement procedures.

Maintenance Responsibility Understood. Almost every successful program clearly defined maintenance responsibilities. In several cases, a stormwater utility district was developed as a funding mechanism. In others, regional facilities were maintained by homeowners' associations. Enabling legislation withstood legal challenges.

Public Relations Programs Successfully Executed. These appeared to ensure the cooperation of the general public.

Table 5

Sewer Replacement and Upgrading Expenditures for
the City of Edmonton (Reference 3)

Year	Costs
1984	$14.36 M
1985	8.60 M
1986	14.37 M
1987	16.22 M
1988	26.04 M

An ambitious program that Edmonton has undertaken, beginning in 1978, is the local Combined-Sewer Relief Program. This is a 22-year program, costing over $130 million, to upgrade approximately 80 km of lateral sewers in the combined drainage area (4.86 ha in area) in order to increase the service level from 1-in-2-year design storm intensity to 1-in-5-year design storm intensity. The number of basement flooding complaints in the upgraded areas has decreased significantly since this program began.

Construction Methods and Materials

Trenchless Methods of Sewer Replacement. As more and more sewer replacement works have to be carried out built-up areas, the so called "trenchless" methods become more attractive. These trenchless methods basically include three categories: tunneling, in-situ pipe repairs, and in-situ pipe replacements. Tunneling is used to install new pipes or to replace existing pipes, while in-situ pipe repairs involve repairing the old pipes without removing them. In-situ pipe replacements, on the other hand, result in removal or demolition of the existing pipes underground and their replacement with new pipes. All these methods require only minimum excavation and surface disturbance and are extremely attractive in restricted and busy areas. Some of the better known trenchless methods are insituforming, pipe insertion method (PIM), resin injection method (RIM), jet drilling, soil displacement hammering, shortcreting, microtunneling, slurry boring, pipejacking, relining and augering. The City of Edmonton has used several of these methods successfully in the past.

Modern Materials and Equipment. Another development in the drainage construction field is the invention of newer materials and more sophisticated equipment. Materials that are easier to install or last longer have been developed. Also, more is known about the effects of chemical and micro-organisms in the sewage and soil medium on pipe materials and thus the service life of pipes can be improved. Modern equipment is designed to speed up the installation process. Some of the compactors or tunneling machines can be remotely controlled which alleviates a major safety problem of having people work in potentially hazardous situations. Other modern equipment, such as lasers, provides greater accuracy in pipe-laying and -tunneling.

Better Project Management Systems. Another development that meets the challenge of higher productivity and efficiency is better project management systems. These systems use microcomputers to help monitor and control costs. The City of Edmonton is using a computer-driven geographic-based information system (GBIS) to compile information relating to location and details of all city-owned utilities. This greatly facilitates the transfer and update of information which is crucial in minimizing unnecessary breakage of utilities during underground construction. The private industry in Alberta is also operating on "Alberta 1st Call" system whereby allocation details of major oil and gas pipelines are channelled to one organization that can provide valuable help to anyone doing underground excavation to avoid costly accidental breakage on these lines.

New Approach to Construction. There are numerous other challenges in the drainage construction sector. One such challenge is the ever-growing problem of I/I into the sanitary sewer system discussed earlier in this paper. This challenge can be met with different design assumptions but it can also be met with a new construction approach. More careful installation coupled with denser materials with better joints can greatly reduce I/I. Installing pipes in separate trenches or separating them with impervious material when installed in common trenches will also help.

Competition in drainage construction is becoming stronger. Works traditionally done by direct labour hired by local governments are increasingly being taken over by the private sectors. There are more private contractors entering the business to build, operate, and maintain drainage systems. This is more noticeable in Great Britain and the U.S., but it is also growing in Canada. No doubt this will bring on higher efficiency from the public sector in some cases, while creating healthy competition to keep costs down. Some local governments have responded by forming quasi-government bodies, such as water boards or storm water authorities, to react to the competition so that they can operate like private companies with minimum government interference and bureaucracy.

PROJECT COSTS

Total Cost Concept

Although there is a general conception that works done by private contractors are cheaper than similar ones done by the public sector, one has to be careful when comparing the costs. It may seem that when estimates or project costs are compared, private contractors' prices are usually by up to 30 percent lower than those from the public sector. However, in most cases there are other relevant intangibles to be taken into consideration. The public sector is mostly under the close scrutiny of the public and is constantly questioned by elected representatives. Public employees tend to place more emphasis on the quality of the work done than the quantity. The general public, though paying more for the construction work, usually get in return other intangible benefits, such as quicker response to complaints, more cooperation in minimizing inconveniences, and less disruption to the environment with cleaner sites, less noise pollution, etc. Therefore, the general public, by paying more, is sometimes getting something in return indirectly.

This discussion leads to the topic of 'total cost concept'. It seems that more and more emphasis is placed on the economic factor. People tend to look at construction costs only. When alternatives are compared, usually the one with the lowest estimate is chosen. However, it should be realized that there are limitations to this approach and when one compares estimates and costs, one has to find out what the estimates and costs include. Do they include only the physical portion of the project or do they also include the intangibles that are more difficult to define? Do they include the "social cost" on which it is practically impossible to put a dollar value? Do they include future operating and maintenance costs? Do they include risks? Do they include secondary benefits, such as awarding a contract to a charitable organization that will hire unemployed people to train them and enable them to become employable, thus keeping them away from drawing Unemployment Insurance? All these questions have to be answered before one can really say which is the cheap alternative. It is a great challenge for us to take this approach, and it is an equally great challenge to develop tools and databases to help decision-makers in making the right choice.

Financial Surcharges

Another topic arising from the greater public demand for information is the use of surcharges for upgrading projects. Edmonton has in the past years introduced several water and sewer surcharges to help fund watermain and sewer relief and replacement projects. Table 6 is a list of current surcharges in effect.

Table 6

City of Edmonton Water and Sewer Surcharge Rates 1989

Item	Monthly Charge
Cast-iron watermain upgrading	13.5% of metered water bill
Local combined-sewer relief	\$2.00 per residential customer; \$0.07/m^3 of water used for commercial and industrial customers up to a maximum of \$25
Local sewer upgrading	\$1.80 per customer

The objective of this approach is to make citizens aware of what some of their utility payments covers. This stemmed from the greater demand for a better return on money paid to the government and more information on how it is spent. More responsive accounting and cost control measures for public funds have to be set up to keep track of them and to explain to citizens where and how their money is used. This surcharge approach has also an added advantage in that in some situations, such as garbage collections and water consumption, it will help to provide an incentive for people to conserve. By showing them how much they have to pay to dispose of their garbage, they will have second thoughts before throwing something out.

CONSTRUCTION STANDARD

Responsibilities of Owners, Builders, and Developers

When we describe our urban drainage system, we do not simply mean the sewers in the street, the sewage treatment plant down by the river, or the lift station next to the valley. We should also include the numerous miles of small pipes branching off the main sewers going into the tens of thousands of houses. A lot of the problems that exist in the drainage system originate from these usually unnoticeable, but crucial, components of the system. Cross-connections, subsidences, collapses, and excessive infiltration through cracks or open joints occurring at the service pipes create significant capacity and pollution problems to the whole system. The City of Edmonton has just recently approved an expenditure of $17 million to rectify a frequent basement flooding problem in a 124-hectare subdivision which is plagued by excessive rainfall-dependent I/I into its sanitary sewer system.

Even though the house connections appear to be a small part of the whole system, they are the ones most difficult to control because of the large number of parties involved from the land development stage to the final house construction. It is very difficult under the present regime to ensure that things are done properly. The developer builds the main sewer network and then each individual builder adds the connection pipes into the system. In the process, there are numerous chances for things to go wrong. The problem can be compounded when the construction of the main sewer and the service pipes are inspected by different inspectors from different departments.

One can easily see that there are too many uncertainties and too few checking processes under the present arrangement. To solve the problem, it will take a great deal of cooperation among the major players, namely, the owners, the developers, the builders, and the policy makers, to come up with a system that will provide clear responsibilities and full accountability from the initial stage to the final completion in the construction of the drainage system. Perhaps the owner may have to assume the responsibilities of both the developer and the builder, and one inspector will look after the job from the beginning to the end to make it work.

Standards Enforcement

The policy-maker can help the industry a great deal in facing the challenge of ensuring properly built drainage systems. The first thing that can be done to eliminate some of the unnecessary rules and procedures. It is no surprise that even some of the most experienced people in the land development field do not know all the steps they have to take to get the necessary approval before they can build the system. What this creates is a huge maze where no one understands clearly what needs to be done and this can easily lead to unclear responsibility. When things go wrong, it is extremely difficult to determine who made the mistake and when the mistake was made. If procedures for approval and inspection can be simplified, it not only results in a saving to the developer, which will in turn benefit the homebuyers, but also reduces the chance of things going wrong. The procedures and bylaws should be clear, concise, effective, practical, and responsive to public concerns.

It is our feeling that the trend will be toward a simpler and clearer planning and development control process. There will be an increasing cooperation among different levels of government, different government departments, owners, developers, and builders in the future, so that everyone will be working toward the same goal of building better drainage systems to serve the public.

Operations and Maintenance Trends

The objective of operations and maintenance activities is to keep the drainage collection and treatment facilities operational with a minimal amount of interruption and inconvenience to the users. We are fast realizing, however, that there is a major problem, not in the future but now, as we approach the last decade of the twentieth century.

Level of Maintenance Required. Ideally all maintenance should be preventive rather than corrective. At selected times on a predetermined schedule, maintenance activities are carried out. These activities should be designed, from a content and frequency viewpoint, to ensure that the facilities will perform the tasks for which the system was originally designed. However, an ever-increasing amount of O&M time is being spent on corrective and emergency activities. Such tasks as the addition of extra catchbasins, repair of seriously deteriorated manholes, and measures aimed at reducing system I/I become part and parcel of O&M activities. Normal preventive maintenance, such as line flushing and catchbasin cleaning, may not be done as scheduled because of the shortage of staff.

Inventory. A major challenge in large urban areas is knowing not only what is in the ground but also the state of repair. Inventory programs are expensive because of the sheer number of components to be inventoried. In Ontario, a government-sponsored program, Lifelines, entails the preparation of a computerized inventory of all drainage system components of an urban drainage system. Special packages have been developed (SIMS for sewers, WIMS for water distribution systems) and the information collected and stored can be the launch-pad for an effective, ongoing maintenance and rehabilitation program. There is a strong argument for other provinces to follow Ontario's example in this initiative.

Training. The ever-increasing technical aspects of drainage system O&M have presented municipal authorities with the further challenge of training personnel. Employees must be trained in the technology and equipment associated with

- closed-circuit TV,
- dye-testing and source detection methods, and
- oil and chemical spill prevention and handling.

The City of Edmonton has instituted for O&M personnel in-house courses and seminars in computer literacy, operator certification, and other areas. O&M personnel need these skills to manage their operations effectively, particularly the quick response that is required under emergency conditions.

Customer Expectations. The greatest challenge facing an O&M team is to meet the expectations of today's homeowners. With increased affluence in the last few decades, expectations of our system's performance have sky-rocketed. Basements of homes owned by people in the 1920s and 1930s were for storage and furnaces. In the 1980s, we invest heavily in developing our basement areas, in many cases building in living spaces of higher quality and cost than those of the upper floor., That our drainage collection systems might be designed to surcharge and that our pump stations might be subjected to power failure or a serious equipment malfunction, these are issues that seldom arise until the first flooding event. There is an enormous need to educate people with respect to the design basis of our urban systems, and the people with the greatest interaction with residents are O&M staff.

CONCLUSION

Edmonton has had an interesting history, development-wise, since its inception. We tend to concentrate on the recent past, and we have vivid memories of the problems the boom period caused in Edmonton and other cities that experienced a similar frantic growth rate during the early 1980s. In looking ahead, we should consider some of the lessons of earlier years. Back in 1910, Mr. Alexander Potter, a New York consulting engineer, planned the backbone of our existing sewer system. In his report, he said:

> "The City of Edmonton in 1890 was nothing but a small trading post, in 1900 it had a population of some 2,500 people, and in 1910 the population is

> roughly estimated at 26,000. To project with any reasonable degree of accuracy the possible population of Edmonton within the next 10 or 20 years, is a problem which the consulting engineer cannot solve, as it depends upon so many uncertain elements which place the problem largely outside of the realm of engineering. Any estimate of what the population of Edmonton will be in the year 1920 or 1930, is the merest king of conjecture. There are conditions possible of fulfilment which might make the population of Edmonton even greater than that predicted by even the most enthusiastic Edmontonian."

Three-quarters of a century later we are facing a brand new century. We can still only speculate on future population trends. However, we do have a great deal of experience to draw upon and we can anticipate the following requirements:

- better protection of property,
- the unacceptability of basement flooding,
- the improvement of tighter controls on lot grading, inspection of connections, and certification,
- the orderly development of areas, only where adequate trunk lines exist,
- resolution of who initially pays for oversizing trunk lines for future development, developer or municipality, and
- an all-embracing, easy-to-follow, yet speedy development application approval process.

These and other issues should be addressed in a comprehensive master plan. Traditionally, master plans deal with capital expenditure items, such as upgrading relief works, rehabilitation, expansion, and operational and maintenance issues. But the master plan must also include a range of options to enable decision-makers to select the acceptable and affordable level(s) of service. The final decisions are made through an extensive consultative process involving the municipality, the development industry, and citizen groups.

A major challenge is to address all issues of interest to these parties:

- in a timely and accurate manner,
- at an all-encompassing macro-scale for the entire city,
- at a sufficiently detailed level to address particular localized problems, and
- in one set of up-to-date reference documents that are simple to understand yet comprehensive in nature.

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MANAGEMENT OF URBAN INFRASTRUCTURE

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ABSTRACT

This paper advances techniques for estimating the funding needs and the allocation of funds in a rational manner to maintain urban assets. At the outset, the magnitude of the infrastructure problem is outlined. Methodological improvements for the management of public works facilities are next discussed. Techniques described here are intended to deal with intersectoral (i.e., roads versus sewers) and intrasectoral evaluations and programming of investments. Ideas are advanced on the incorporation of technological improvements, such as the Geographical Information System (GIS), into the methodological framework.

RÉSUMÉ

Le présent exposé fait part de techniques rationnelles d'évaluer les besoins de financement et d'affecter les fonds de manière à sauvegarder l'actif urbain. Au départ, il fait ressortir l'ampleur du problème des infrastructures, puis traite d'améliorations méthodologiques concernant la gestion des installations publiques. Les techniques décrites ici visent à une évaluation intersectorielle (voies et chaussées par opposition aux égouts, par exemple) et intrasectorielle, ainsi qu'à l'établissement de programmes d'investissement. Des idées proposent notamment de suivre l'évolution technique en faisant appel, par exemple, au Système d'information géographique (SIG) dans le cadre de travail méthodologique.

INTRODUCTION

Infrastructure is extremely important for the proper economic functioning of an urban society. In fact, urban society could not exist without the sophisticated urban infrastructure present in our modern cities. Also, the value of these assets represents considerable sums. The management of these assets, therefore, is a very important function of municipal governments if we mean to avoid leaving the next generation a mountain of rehabilitation costs. Cities must therefore learn to manage their infrastructure like a business and allocate funds in a rational manner to maintain it.

MAGNITUDE OF THE PROBLEM

At the international level, the developing countries have lost precious infrastructure, worth billions of dollars, through deterioration of their roads. In 85 countries that have received World Bank assistance for roads, a quarter of the paved roads outside urban areas need reconstruction as do a third of the unpaved roads. This work will cost $40 billion to $45 billion. Timely preventive maintenance costing less than $12 billion could have saved these roads (World Bank, 1988).

In the U.S., various studies have been conducted which attempt to estimate the annual shortfall between investment requirements and available revenues to undertake the necessary rehabilitation work. The estimates vary from $17.4 billion (Congressional Budget Office, 1983) to $24.6 billion (Joint Economic Committee of Congress, 1984) to $71.7 billion (Associated General Contractors of America, 1983) (National Research Council, 1987). Estimates of the backlog regarding the maintenance and repair of bridges, streets, and water and sewer systems range from less than $1 trillion to over $3 trillion. U.S. spending on public works decreased from 19.1 percent of total government expenditures in 1950 to 6.8 percent in 1984.

The U.S. Transportation Department calculated that in 1985, vehicles on U.S. freeways racked up 722 million hours in delays (a number that is expected to rise to 3.9 billion hours by the year 2005, if no improvements are made). If we use an average wage of $10/hour, costs of delay amount to over $7 billion per year. These are staggering figures which may overstate the problem. The National Council on Public Works looked at this problem in another manner. Warning that the nation's public works are badly in need of attention, the results of the 2-year study recommended a doubling of funds to help save the nation's crumbling infrastructure. The study graded progress in eight categories of public works.

FIGURE 1
THE STATE OF PUBLIC WORKS (U.S.A.)

HIGHWAYS	C+
MASS TRANSIT	C-
AVIATION	B-
WATER RESOURCES	B
WATER SUPPLY	B-
WASTEWATER	C
SOLID WASTE	C-
HAZARDOUS WASTE	D

Source: "Fragile Foundations, A Report on America's Public Works". National Council on Public Works.

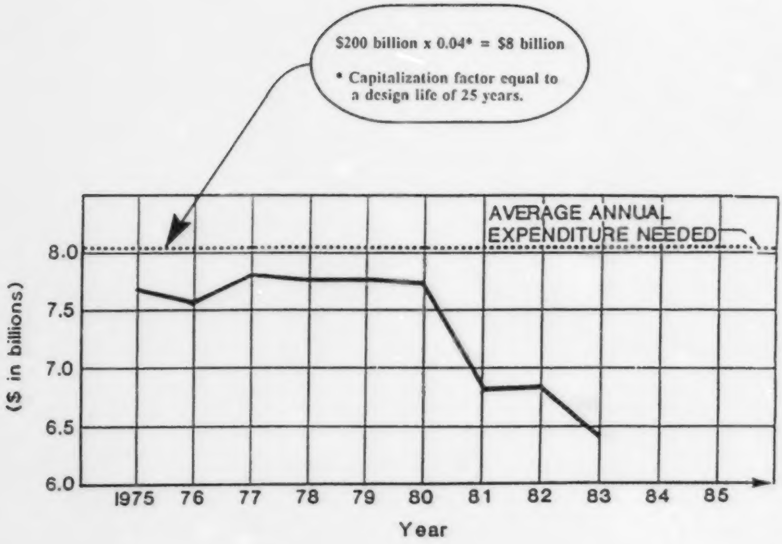
In Canada, several agencies have attempted to quantify the magnitude of the lack of maintenance. TRIP/CANADA, a public information committee of the Canadian Construction Association, has over the last several years published many reports on the magnitude of the infrastructure rehabilitation problem for the municipal and provincial roadway systems in every province. Although these agencies have a vested interest, the numbers are still worth contemplating. For example, in June 1987, TRIP/CANADA (Ontario Chapter) published a short paper on the evaluation of the sewer systems in Ontario. According to TRIP/CANADA, 12,000 km of sewer and service connections in Ontario must be reconstructed over the next 70 years at an annual present-value cost of $107 million a year. TRIP/CANADA documents that Ontario residents served by municipal water distribution systems may find these systems unable to deliver a reliably adequate supply of water because of rapidly advancing system decay. The TRIP/CANADA reports go on to state that without immediate corrective action, users of these systems face service disruptions caused by breaks, wastage through undetected leaks, and loss of the water pressure needed by fire protection services. TRIP/CANADA estimates that $141 million is required annually (about 2.5 times the current level of spending) over an extended time frame to rehabilitate the province's watermains and related services. The replacement value of the water system in the province is estimated to be $20 billion (TRIP CANADA, 1987). Similar studies have been done in other provinces.

On a larger scale, the Federation of Canadian Municipalities (FCM) sent a questionnaire to 300 member municipalities across Canada. Of the 33 Canadian cities with populations of more than 100,000, twenty responded to the questionnaire, including eight with populations of over 400,000. The population of the 71 responses (8.8 million) represents almost 50 percent of the nation's cities over 10,000 persons. Although the questionnaire method is a crude manner to determine "needs", the results nevertheless illustrate that a problem of significant proportions exists in Canada. The total cost to upgrade their infrastructure (sewage collection treatment, water distribution, and treatment of roads and bridges) is estimated to be approximately $16 billion in current dollars. This has been referred to by the Mayor of Edmonton as the "Big Fix".

The Roads and Transportation Association of Canada (RTAC) in a recent paper (RTAC, September 1987) indicated that to maintain assets at an acceptable level of service (without allowing for growth in demand) would require annual expenditures in the order of $8 billion. Current (1983) expenditures are in the order of $6.5 billion, i.e., a shortfall of $1.5 billion annually (see Figure 2). RTAC estimated that the total value of federal, provincial, and municipal roads is in the order of $200 billion. Parks Canada, as another example, has approximately $3 billion in infrastructure assets, one-third of which is roads.

It has been suggested that perhaps we cannot afford our present infrastructure. That urban transport plays a major role in the economic efficiency of cities is evident from the very high economic rates of return that have been achieved mainly from the considerable savings and the reduction in vehicle operating costs. Estimated rates of return have been high for all types of urban projects but particularly for urban transport projects as is evident from Table 1. Unfortunately the same type of rigorous economic cost-benefit analysis is not performed for a majority of urban Canadian transport projects, but it is felt that the rates of return would be similar.

FIGURE 2
HISTORICAL EXPENDITURES VS NEEDS
TOTAL CANADIAN SYSTEM
RTAC SEPTEMBER 15, 1987
(In Constant Dollars)



$200 billion x 0.04* = $8 billion

* Capitalization factor equal to a design life of 25 years.

Table 1
Average Economic Rate of Return for Urban Transport Projects

Fiscal Year	Rate of Return	Number of Projects
1973	37.0	1
1974	19.5	2
1975	0	0
1976	30.0	1
1977	28.0	1
1978	34.0	2
1979	28.0	1
1980	23.0	1
1981	50.0	1

Source: Urban Transport, a World Bank Policy Study

DISCUSSION OF ALTERNATIVES

It is now apparent that our older cities have to catch up on an enormous backlog of neglected maintenance. Rehabilitation of infrastructure is not an exciting issue on which to run for re-election, but supplying basic services is one of the main purposes of municipal government. If municipalities cannot rise to the task, perhaps better provincial policies will be the prerequisite for better municipal policies as has been historically the case (Bird & Slack, 1983).

In managing public infrastructure subsystems, it has been an all too common practice to make decisions based upon annual budgets without regard to long-range trends in system conditions and projected resources. This situation has been exacerbated by the growing fiscal gap between public works funding and the escalating cost demands of a generally deteriorating infrastructure, leaving those responsible for infrastructure maintenance to respond to one crisis situation after another. Consequently, projects are often designed and implemented incrementally, based on the current or, at best, the next budget cycle as funding dictates rather than as elements in a planned sequence of system maintenance and improvement.

Maintenance and depreciation have been neglected in many infrastructure systems because since it is easier to defer them from one political administration to another. There is more glamour in building new projects than maintaining old ones.

Grigg (1985) has stated that effective public works management is the most important ingredient in solving the infrastructure problem. Perhaps, new approaches and performance measures are required. Approaches, such as the evaluation of assets, can be used to systematically address the problem of defining the proper expenditure levels. Depreciation is an allocation of the cost of fixed assets. It does not necessarily agree with actual wear and tear, physical conditions, or productive ability of the assets involved. There are no uniformly acceptable estimates of useful life. Facility deterioration depends on many major factors, including initial design and quality of construction, use of the facility, and conditions to which the facility has been exposed. Nevertheless, the private sector uses depreciation as a rough estimate of what must be invested to ensure productive capacity.

Extrapolating past trends of investment levels in a particular sector and using a replacement cycle as a rule of thumb allows one to forecast future needs. Such approaches are necessary in the absence of good information, but are likely to produce a crude estimate of real investment needs. Depreciation can be used as a rough estimate to be modified by an internal list of both intersectoral and intrasectoral needs. Further research can define the remaining useful life (RUL) with more precision.

Maintenance of infrastructure is a local, provincial, federal, and international problem. The first problem is to properly define an adequate funding level to maintain our assets. The second problem is getting political and financial commitment, which requires innovative funding techniques. Mr. M. Sheflin, Commissioner of the Transportation Department of the Regional Municipality of Ottawa-Carleton, has been a long-time advocate of a partially dedicated gasoline tax of, say, approximately $0.04/litre. The Province of New Brunswick is the first to attempt this approach. A dedicated tax of 4 or 5 cents per litre would go a long way to finance our crumbling infrastructure.

METHODOLOGICAL ISSUES AND SOLUTIONS

Management requires a re-orientation of how it thinks about infrastructure. Cities need to manage their infrastructure the way a business manages its assets. Among the questions to be asked, therefore, are:

(1) How do we properly define our needs?

(2) What is the "right" sustained funding level to manage each of our assets?

(3) How do we maintain a current infrastructure inventory?

Inventorying and Defining Needs

An approximation to the first question can be obtained by using the Martin-Khan equation:

$$F\text{-}L = C_R V_R + C_{SS} V_{SS} + C_{ST} V_{ST} + C_W V_W + \ldots\ldots C_L V_L \qquad -1$$

where,

F-L = annual funding level

CR = capitalization factor for roads

= $1/D_R$

D_R = design life of Roads (in years)

V_R = replacement value of Roads

C_{SS} = capitalization factor of sanitary sewers

= $1/D_{SS}$, where D_{SS} is the design life of sanitary sewer (in years)

V_{SS} = replacement value of sanitary sewers

C_{ST} = capitalization factor for storm sewers

= $1/D_{ST}$, where D_{ST} is the design life of storm sewer (in years)

C_W = capitalization factor for watermains

= $1/D_W$, where D_W is the design life of watermains (in years)

C_L = capitalization factor for libraries (in years)

= $1/D_L$, where D_L is the design life of libraries

Three examples, incorporating the design lives shown in Table 2, illustrate the usefulness of the equation.

Table 2

Typical Design Life Values and Recapitalization Factors

	Design Life (years)	Recapitalization Factor
Buildings	20	0.05
Roads and bridges	25	0.04
Parks landscaping and improvement	25	0.04
Vehicles	4 to 7	0.14 to 0.25

Source: Annual Report 1986-87 National Capital Commission

In Example 1, the investment level required to maintain our $200 billion assets in national roads has been calculated, in the second example, the effect on a City's budget (in this case the City of Ottawa), and in the third example, the recommended value of annual watermain expenditures in Ontario (TRIP-CANADA).

Example 1

Given:

Value of federal, provincial, and municipal roads in Canada = $200 billion

Design life approximately = 25 years

Capitalization ratio = 1/25 = 0.04

Recommended Annual Expenditure

= 0.04 x 200

= $8 billion annually (exactly the figure recommended by RTAC)

Example 2

Value of roads = $700 million

Value of sewers = $600 million

Recommended Annual Budget (using the Martin-Khan equation)

= $700 million x 0.04* + $600 million x O.02**

= $28 million (for roads) + $12 million (for sewers)

= $40 million

Present Ottawa Budget Request for 1989 and 1990

Roads = $15.5 million

Sewers = $10.7 to $15 million

TOTAL: $26.2 to $30.5 million

Example 3

Given:

Value of watermains in Ontario = $20 billion

Design life = 20 years

Capitalization ratio = 1/20 = 0.05

Annual expenditure = 0.05 x 20 = $100 million/year (compared to $141 million recommended by TRIP-CANADA)

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* design life 25 years

** design life 50 years

"Right" Sustained Funding Level

Although crude, the equation would provide minimum sustained investment levels for infrastructure rehabilitation. There could be, for example, a statutory requirement not only to carry the value of the infrastructure on the "books" of the municipality, but also to indicate the annual depreciation. During tight financial times, this could be a condition of the experts who perform credit worthiness evaluations of municipalities to ensure that sufficient sums are invested in maintaining the assets of the corporation.

The formula does not account for growth-related issues. Growth-related problems with respect to capacity of existing infrastructure would have to be addressed by "impact fees" or redevelopment charges.

Maintaining a Current Infrastructure Inventory

A survey of local officials, sponsored by the International City Management Association in the U.S. in 1987, revealed that only 60 percent of U.S. cities and counties have a complete, current infrastructure inventory. Without such basic information, governments at all levels are hard-pressed to plan effectively for their capital asset needs (National Academy of Engineering, 1988). The City of Scarborough, Ontario (population: 500,000), for example, has introduced a computer database for its 2,200-km sewer system. With a replacement value of over $2 billion, it is estimated that there has been a 5-percent increase of productivity in the maintenance operation. Due to improved coordination of maintenance and construction, the money spent to implement the system yielded a 33-percent return on investment.

Infrastructure management systems, such as Sewer Information Management Systems (SIMS), Watermain Information Management Systems (WIMS), Road Information Management Systems (RIMS), and Geographic Information Systems (GIMS), hold great potential for aiding decision-makers in more efficiently and effectively managing the public infrastructure.

Decision-making within local governments today requires assimilation of accurate information from many different sources and agencies. To effectively manage street-paving maintenance programs, utility service systems, and property assessment, local government administrators must have timely and accurate information. They must be able to get it quickly from various maps, drawings, and tabular records. This type of infrastructure-related information is usually obtained from numerous and often out-of-date manual mapping and engineering drawing sheets and right-of-way maintenance record files. Local government administrators are seriously looking at the GIS computer technology which will help them provide more effective levels of service and efficiently handle complex infrastructure management planning problems, and reduce operational costs through preventive maintenance programs. The integration of computerized infrastructure inventory records, computer-aided engineering and computer-mapping applications into one geographical database system enables us to build an intelligent Infrastructure Management Information System (IMIS). IMIS allows the storage of important information about municipal resources and facilities such as street networks, traffic signals, and land records, as well as engineering, digital terrain, and economic development models in the form of "electronic maps", which can be recalled in a matter of seconds and displayed on a graphics computer terminal to promote more informed, timely, and productive decisions.

The methodological framework incorporating techniques for making intersectoral infrastructure evaluations and program development is shown in Figure 3. The initial step is that of deciding which sectors are to be studied within the framework for assessing funding needs. For example, a given municipality may wish to study roads, transit, water and sewer works within a common framework and deal with other infrastructures separately.

Another issue that has to be raised here is that of the rehabilitation of existing facilities as opposed to building new ones. The methodological framework, in its present form, is directed toward solving the problem through rehabilitation, although extensions can be made to bring the wider question of the competition of new and existing facilities for inclusion into investment programs.

The gross funding level can be estimated from the application of the Martin-Khan equation described earlier. The following step requires the identification of projects that are interdependent, both within and between sectors. The identification of interdependencies would be facilitated by the information systems. Following the structuring of projects (of dependent as well as independent types), their cost effectiveness (as a proxy measure for benefit-cost information) has to be established. For program development purposes, the drop in effectiveness of rehabilitation works due to a delay in their implementation can be estimated.

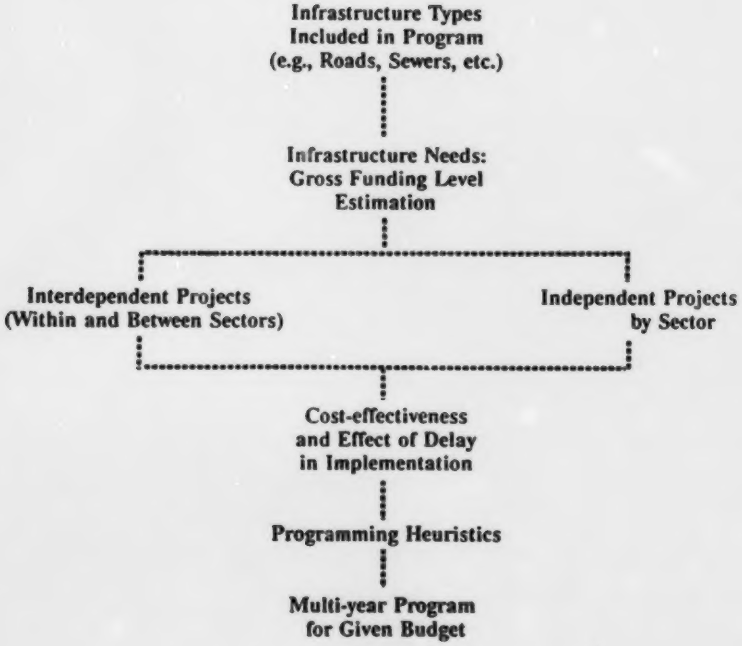
Infrastructure Types
Included in Program
(e.g., Roads, Sewers, etc.)
Infrastructure Needs:
Gross Funding Level
Estimation
Interdependent Projects
(Within and Between Sectors)
Independent Projects
by Sector
Cost-effectiveness
and Effect of Delay
in Implementation
Programming Heuristics
Multi-year Program
for Given Budget

FIGURE 3: METHODOLOGICAL FRAMEWORK

The cost-effectiveness evaluation information is to be used in a heuristic manner for program development under budget constraints. More sophisticated techniques, such as artificial intelligence/expert programs for the optimal combination of projects involving dependent and independent projects, could be used. Expert systems have the potential to play a very significant role in addressing these problems (Ritchie, 1987).

CONCLUSIONS

Combining an infrastructure management strategy with the methodological framework and techniques described here ought to go a long way in avoiding our leaving the next generation with a mountain of rehabilitation costs. The computerized databases, minimum funding levels established by the proposed equation, the evaluation and programming techniques, and financial innovations described are believed to offer some solutions to the infrastructure management problem.

ACKNOWLEDGMENTS

The authors are grateful for information provided by numerous persons and institutions. The financial support from the Natural Sciences and Engineering Research Council of Canada and the Delcan Corporation is gratefully acknowledged.

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THE IMPACT OF STREET MAINTENANCE PROGRAMS ON THE CALGARY INFRASTRUCTURE

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T2P 2M5

ABSTRACT

The purpose of this paper is to discuss how street maintenance programs impact on the Calgary infrastructure, how the programs are planned, and how their priorities are set. The programs are divided into operations and maintenance. Operations is primarily concerned with snow and ice control, street cleaning, and environmental control along the rights-of-way of streets. Maintenance is concerned with gravel roads and lanes, portland-cement concrete sidewalks, curbs, gutters, and some streets as well as asphaltic concrete streets.

The following steps of the annual work plan are discussed: determine community need, formulate program goals, implement program, evaluate efficiency, evaluate effectiveness, evaluate cost benefit, and then reassess community need. For example, this process now shows that we can cut back the asphalt overlay program. Specific plans are discussed which have been produced for street cleaning, snow and ice control and asphaltic concrete repairs. The portland-cement concrete repair plan is currently under revision. The constraints on the annual work plan of the budget set by city council are also discussed.

To satisfy budgetary constraints this paper examines how all work is prioritized. The following prioritization issues will be commented on: public safety is paramount, thus pothole repairs, emergencies due to snow conditions, debris on street carriageways are the first priority. Over the years, criteria for levels of service have been established. These criteria impact on priorities. The anchor point for setting priorities is the street inventory. An annual condition survey of the inventory is used to establish the street maintenance workload. The workload is prioritized according to severity of defect. A pavement management system (PAVER) is used to set priorities for the asphalt overlay program. PAVER is also a source of feedback on the overall condition of Calgary streets.

RÉSUMÉ

L'objet du présent exposé consiste à connaître, à Calgary, l'incidence des programmes d'entretien des rues sur les infrastructures, le mode de planification des programmes, ainsi que la façon d'établir les priorités. Les opérations s'intéressent principalement au déneigement et au déverglaçage des chaussées, au nettoyage des voies, et à la protection de l'environnement le long de l'emprise des rues, alors que l'entretien porte sur les routes de gravier et les ruelles, les trottoirs de béton de ciment portland, les bordures, les rigoles, certaines chaussées et des rues à revêtement de béton asphaltique.

Le plan de travail annuel y est traité selon les démarches suivantes : déterminer les besoins de la collectivité, formuler les buts du programme, mettre le programme en oeuvre, évaluer son efficience, juger de son efficacité, se livrer à une analyse coûts-avantages, puis réévaluer les besoins de la collectivité. A titre d'exemple, ce processus démontre maintenant que nous pouvons réduire les travaux de revêtement d'asphalte. Il est question de plans précis concernant le nettoyage, le déneigement et le déverglaçage des chaussées, et les réparations de béton asphaltique. Le project de réparation faisant appel au béton de ciment portland est actuellement à l'étude. Sont également abordées les restrictions qu'exerce sur le plan de travail annuel le budget adopté par le conseil municipal.

Le document souligne comment l'exécution de tous les travaux suit un ordre de priorité de manière à respecter les restrictions budgétaires. Les questions de priorité suivantes y sont commentées : la sécurité publique domine; c'est donc dire que les réparations ponctuelles, l'urgence attribuable aux conditions d'enneigement, l'enlèvement des débris sur les chaussées s'inscrivent au tout premier rang. Au fil des ans, la municipalité a adopté des critères fixant le niveau de service, qui, bien sûr, se répercutent

sur les priorités. L'état du réseau du rues détermine l'ordre de priorité. Une enquête annuelle sur l'état des rues permet d'établir la charge du travail d'entretien, l'ordre prioritaire dépendant des anomalies relevées. Le système de gestion des chaussées (PAVER) s'utilise pour fixer les priorités dans le cadre des activités de revêtement des chaussées d'asphalte, mais il offre également une source de rétroaction quant à l'etat géneral des rues de Calgary.

INTRODUCTION

The Calgary streets maintenance organization is charged with the responsibility of providing maintenance services for the street system in 1988. The City's street system comprised 4,280 km arterials, collectors, residential streets and lanes.

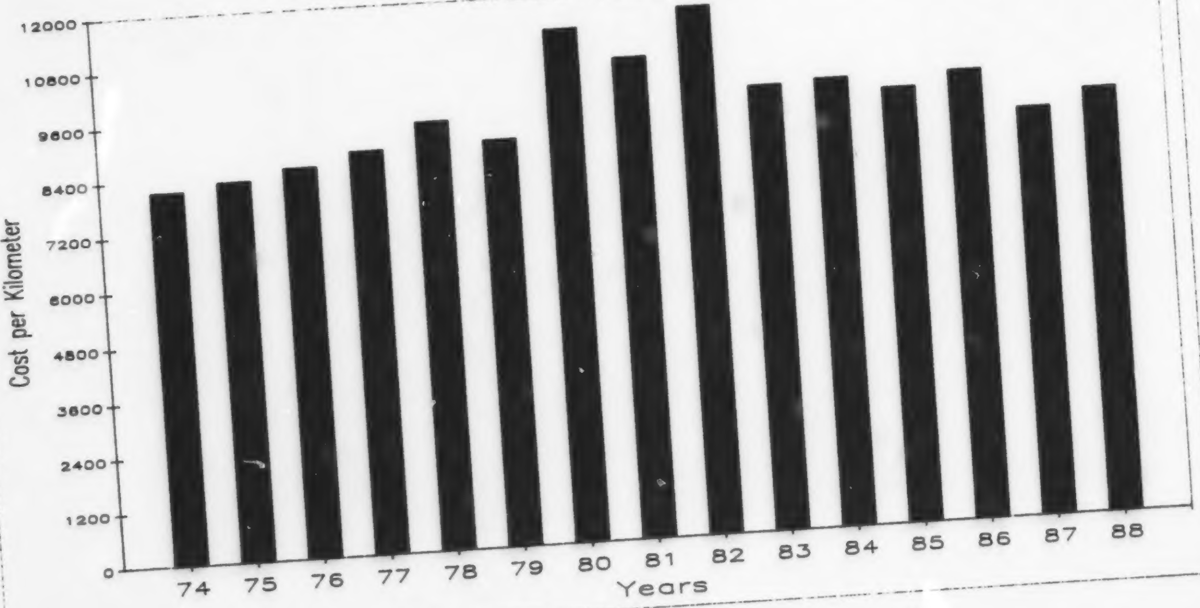
The rapid growth experienced by the City of Calgary over the past 10 years, coupled with an inflationary economic climate, has contributed to the rising cost of maintaining all of the City of Calgary's infrastructure. It is estimated the City will need to invest $188 million in maintaining its infrastructure from 1989 through 1993. Of this amount, $91 million will be an investment in maintenance of the street network. Also during this time, an additional $70 million will be required to operate the street system with respect to snow, dirt, and litter control.

In Calgary, as in any large municipality, public safety is a paramount consideration. Thus, the provision of street system services, such as snow and ice control, and pothole repairs, receives top priority. In this context there is always pressure to funnel funds from preventive maintenance activities to snow and ice control and other streets maintenance activities closely related to safety.

Fortunately, our city council during the past decade has resisted the expedient action by providing adequate funding for snow and ice control, and by allowing sufficient investment in preventive maintenance programs for streets. At the same time, the Engineering Department has made prudent use of funds through a vigorous productivity improvement program.

Although this paper specifically deals with the streets in the Calgary infrastructure, city council has provided similar consideration to waterworks and sewers. The remaining $97 million expenditure estimated for the next 5 years will be applied to preventive maintenance for Calgary's waterworks and sewers.

City of Calgary - Streets Maintenance
Costs per Kilometer in 1988 Dollars
Figure 1



Overall, the Calgary infrastructure is in reasonable condition. This has been achieved, over the years, through prudent investment of the taxpayers' dollars in preventive maintenance programs. Should federal or provincial governments provide assistance to municipalities to maintain or to renew their infrastructure, then this should be done on a per-capita basis. Funding on a per-capita basis would leave the responsibility for upkeep of infrastructure with all city councils. At the same time, it would encourage those who had adequately maintained their infrastructure to continue to do so.

ANNUAL WORK PLAN FOR STREET MAINTENANCE

In response to the downturn in the economy at the beginning of the decade, Engineering Department budgets were reduced significantly. All city departments were faced with the challenge of providing the same level of service with reduced funding. To do this for street maintenance, the annual work plan process, which is used to prepare the annual operating budget, had to be modified to balance efficiency and effectiveness.

Since public safety overrides all considerations in providing services, service level reductions would of necessity have meant a reduction in preventive maintenance. Figure 1 shows a 15-year comparison of the cost to maintain each kilometre of street network in constant dollars. The cost to maintain and operate 1 km of street peaked in 1982; however, the level of service for the most part remained the same for the past decade.

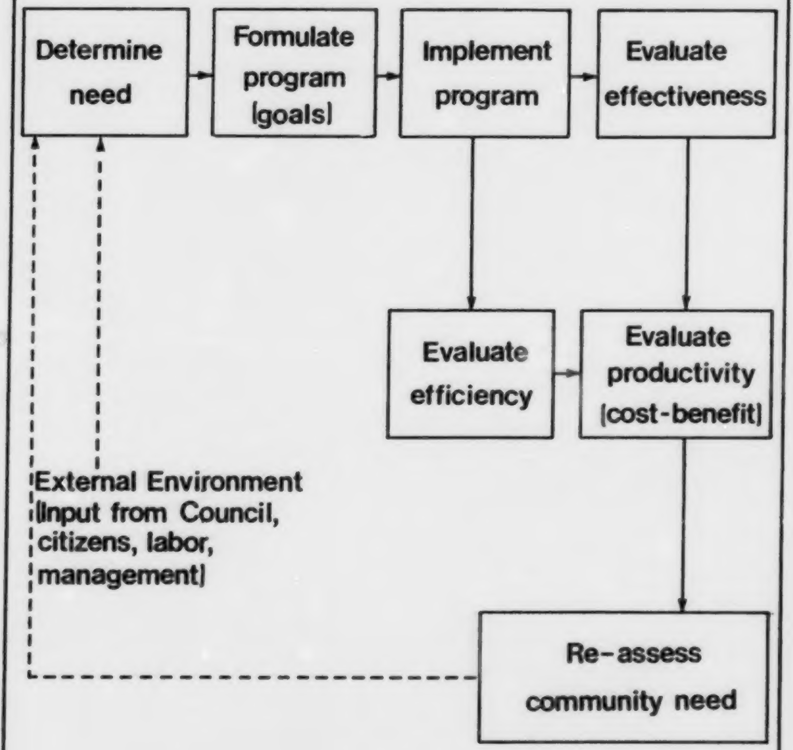

Determine need
Formulate program (goals)
Implement program
Evaluate effectiveness
Evaluate efficiency
Evaluate productivity (cost-benefit)
External Environment (Input from Council, citizens, labor, management)
Re-assess community need

FIGURE 2

Work Plan Process Model

The following process model (see Figure 2) is now used to implement all programs.

Determine The Need. The need has been established incrementally over a number of years through an external environment of input from city council responding to requests from the citizens they represent. During the years of a booming economy the demand for public service goes up, there is more activity going on, more construction, and a greater demand for better streets. At such times it is not too difficult to increase taxes in response to the demand for a higher level of service. On the other hand, when we have a downturn in the economy, the demand for service remains high, yet the will and ability to pay for the service is no longer there.

Formulate Program. Based on the need, program goals are formulated.

Implement Program. Once the program goals are set, the annual operating budget is approved by city council, and implementation begins on January 01.

Evaluate. Evaluation is carried out throughout the year. Program goals become staff performance objectives which are reviewed at mid-year and year end. Reviews ensure efficiency and effectiveness are balanced.

Reassess. Since results are demonstrated on a cost-benefit basis, they can be reassessed as cost-benefits against a community need, and so the process starts again.

Organization

The process model is used in the context of a decentralized organization. For administrative and operational purposes, the street maintenance activities are performed in nine City of Calgary zones. Each zone has approximately 350 km of streets. Experience has shown this decentralized organization renders the following advantages in terms of implementing street maintenance activities:

- prompt response to trouble calls and complaints,
- increased resource utilization, and
- effective planning and control of work programs.

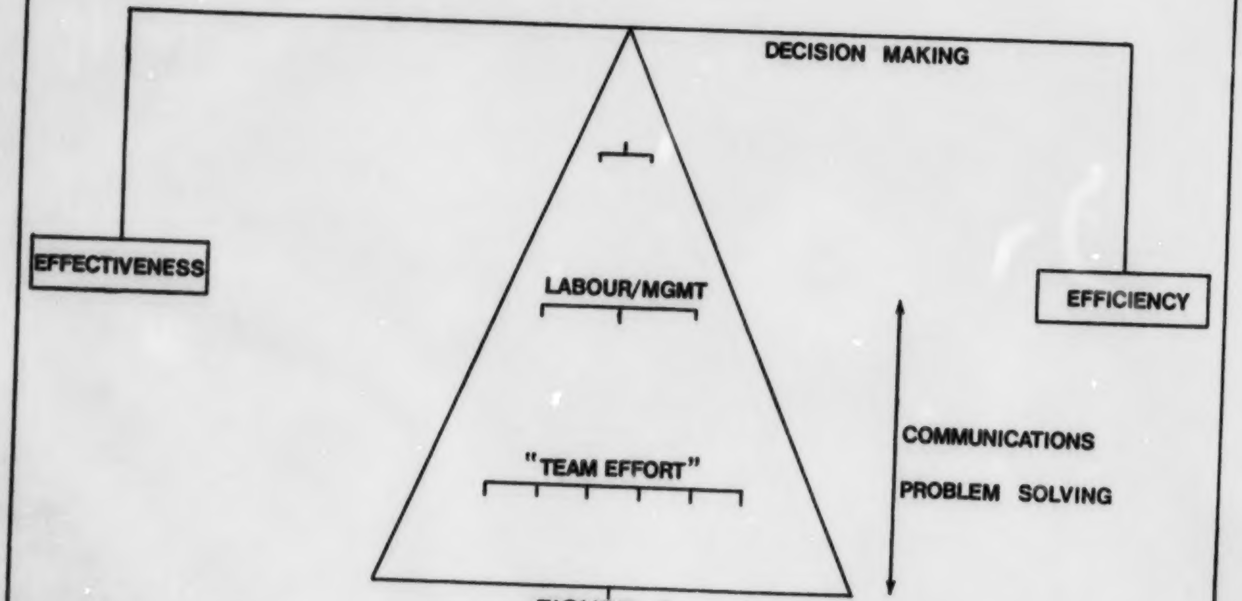
To encourage staff support and involvement, regular labour/management meetings are held. At these meetings, problems and issues related to work practices and procedures are identified, and alternative solutions are then explored and investigated for implementation.

In order to communicate well with all parts of a large decentralized organization there has to be an understanding of the key concepts and definitions.

Effectiveness and Efficiency

Effectiveness is defined as achieving the goal of providing council-approved services to the community. Efficiency is defined as the extent to which resources have been used to provide public services at the lowest possible cost. Efficiency therefore is usually expressed in terms of resource input over program output, while effectiveness relates to goal achievement. A program can be efficient by being very economical without being effective, if it does not meet the quality or timeliness standards of the community.

All our annual work plans attempt to run a balanced course between efficiency and effectiveness. For example, in the sanding and salting operation, a balanced course is to provide, in accordance with level of service policy, snow- and ice-free street surfaces (effectiveness) with minimum input of resources: labour, equipment, and materials (efficiency). Figure 3 aims to illustrate this.



STREETS MAINTENANCE
WORK PLAN
CONCEPTUAL THEME

DECISION MAKING
EFFECTIVENESS
EFFICIENCY
LABOUR/MGMT
"TEAM EFFORT"
COMMUNICATIONS
PROBLEM SOLVING

FIGURE 3

PRODUCTIVITY INDICATOR – EFFICIENCY

ACTIVITY		PRODUCTIVITY INDICATOR		
NO.	DESCRIPTION	LABOUR	MATERIAL	EQUIPMENT
13	PATCHING - HAND CREW	0.39 M-HRS/m^2	0.21 t/m^2	0.34 EQ'T HRS/m^2

FIGURE 4

Productivity Indicators

Existing efficiency and effectiveness indicators are reviewed annually, then modified or new ones developed. Valid productivity indicators have to encompass both efficiency and effectiveness to ensure one factor is not over-emphasized at the expense of the other. The development of efficiency indicators is relatively easy, however, effectiveness indicators are much more difficult. (Figure 4 is an example of an efficiency indicator.) Effectiveness is concerned with goal achievement. A vague goal might be "To maintain Calgary streets in good condition." Calgary uses the APWA pavement management system (PAVER) to establish a pavement condition index (PCI) for all streets as a measure of effectiveness. Thus, the above goal becomes "To maintain Calgary streets at a PCI of 65 or higher."

Other indicators of effectiveness are either under development or have been developed. An automated database program has been developed to provide a systematic means of keeping track of the complaint and trouble call records, since complaints can be used as a measure of effectiveness. Also, effectiveness indices, based on criteria readily understandable by inspection staff, have been set up. The inspection staff use random sampling techniques to provide effectiveness indices for winter driving (WDCI), loose top (LTCI), and street cleaning (SCI).

Setting Objectives

Once the indicators have been established, the primary objective of each maintenance activity is critically examined and reviewed. The objective of the activity has to be consistent and supportive of the mission statement regarding streets. In redefining objectives, it is important to ensure that they are solidly based on desired results, i.e., community needs. Each objective has to be stated clearly and concisely and has to be measurable in terms of time and cost.

Setting Standards

The performance standards (or benchmarks) are derived from historical data. The reasons for choosing this method are:

- It is economical.

- It is suitable for street maintenance activities which have relatively long working cycles, coupled with operating times that are usually influenced adversely by elements outside of the work force's control, e.g., weather and traffic conditions.
- It is consistent with the Calgary's street maintenance work culture. Comparisons to similar unit costs in another city would not take into account the work force culture.

This approach to setting performance standards should be appropriate for any public work activity.

Methods and Procedures

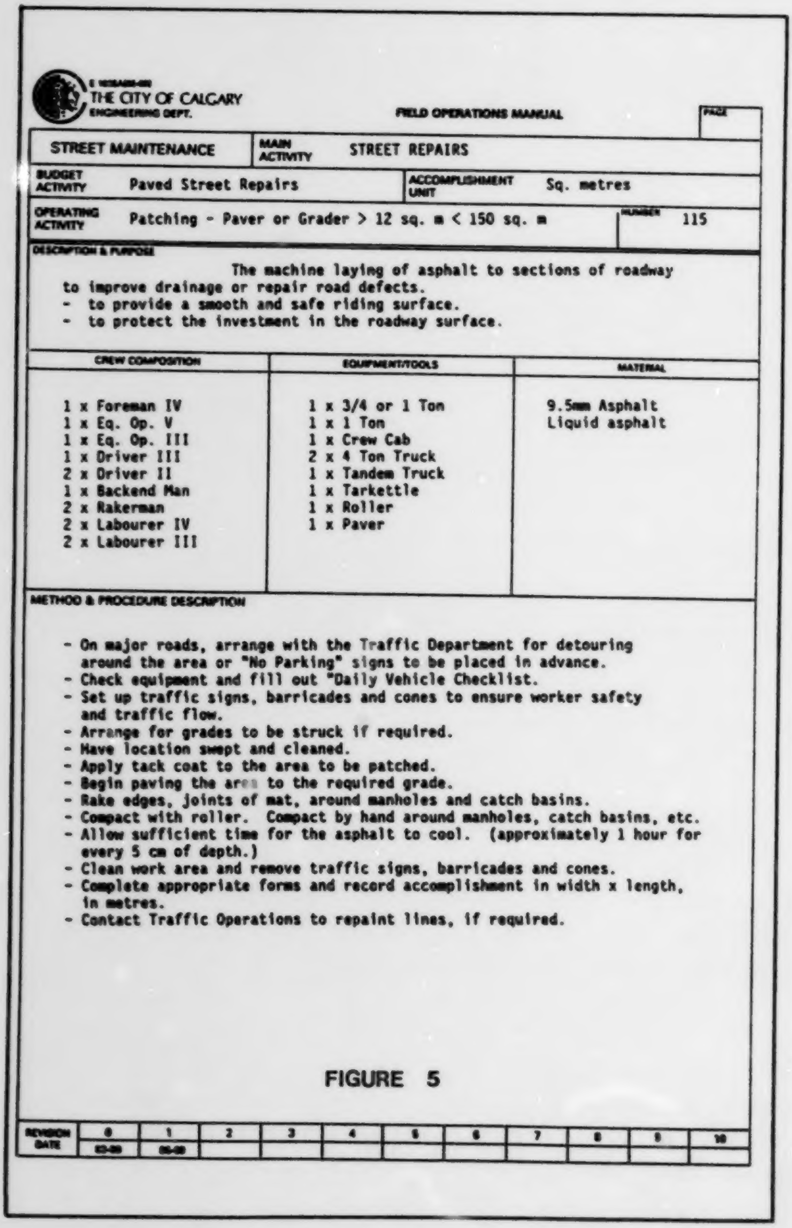
In-depth reviews of the methods and procedures in practice for each activity are conducted to formulate a set of uniform methods and procedures. The team members of this group are selected from all levels of the work force, i.e., supervisors, foreman, and equipment operators.

Manpower composition, equipment, and material requirements for each activity are also examined and standardized. The outcome of this effort is a set of uniform methods and procedures for a given activity performed by a relatively standardized crew. The salient feature of a uniform work method is its capability of facilitating performance comparisons, annual budget preparation, and cost control.

The uniform work methods are contained in the "Streets Maintenance Field Operation Manual". Figure 5 illustrates an example from the manual.

Training

New training sessions for operators assigned to major activities are developed, or training practices already in place are updated. Increased hands-on training sessions are held for new as well as experienced operators. Evidence has shown that these training sessions result in an increase in the operators' awareness of the need to do a quality job; this, in turn, leads to reduced material waste. Productivity improvement achieved in such activities as sanding, salting, and spring clean-up are attributed, in part, to these training sessions.



THE CITY OF CALGARY
ENGINEERING DEPT.

FIELD OPERATIONS MANUAL

PAGE

STREET MAINTENANCE	MAIN ACTIVITY STREET REPAIRS
BUDGET ACTIVITY Paved Street Repairs	ACCOMPLISHMENT UNIT Sq. metres
OPERATING ACTIVITY Patching - Paver or Grader > 12 sq. m < 150 sq. m	NUMBER 115

DESCRIPTION & PURPOSE

The machine laying of asphalt to sections of roadway to improve drainage or repair road defects.
- to provide a smooth and safe riding surface.
- to protect the investment in the roadway surface.

CREW COMPOSITION

1 x Foreman IV
1 x Eq. Op. V
1 x Eq. Op. III
1 x Driver III
2 x Driver II
1 x Backend Man
2 x Rakerman
2 x Labourer IV
2 x Labourer III

EQUIPMENT/TOOLS

1 x 3/4 or 1 Ton
1 x 1 Ton
1 x Crew Cab
2 x 4 Ton Truck
1 x Tandem Truck
1 x Tarkettle
1 x Roller
1 x Paver

MATERIAL

9.5mm Asphalt
Liquid asphalt

METHOD & PROCEDURE DESCRIPTION

- On major roads, arrange with the Traffic Department for detouring around the area or "No Parking" signs to be placed in advance.
- Check equipment and fill out "Daily Vehicle Checklist.
- Set up traffic signs, barricades and cones to ensure worker safety and traffic flow.
- Arrange for grades to be struck if required.
- Have location swept and cleaned.
- Apply tack coat to the area to be patched.
- Begin paving the area to the required grade.
- Rake edges, joints of mat, around manholes and catch basins.
- Compact with roller. Compact by hand around manholes, catch basins, etc.
- Allow sufficient time for the asphalt to cool. (approximately 1 hour for every 5 cm of depth.)
- Clean work area and remove traffic signs, barricades and cones.
- Complete appropriate forms and record accomplishment in width x length, in metres.
- Contact Traffic Operations to repaint lines, if required.

FIGURE 5

REVISION DATE	0	1	2	3	4	5	6	7	8	9	10
	[illegible]	[illegible]									

Information System

The feedback system for the annual work plan is provided by the City's corporate-wide accounting and management reporting system (AMRS). The operating performance summary reports from this system provide the necessary information to monitor and control work performance. These reports include man-hours expended, equipment hours expended, material usage, accomplishment units, etc. This information represents the actual performance levels of the task and can be compared to the standards.

Productivity Improvement Results.

By following the annual work plan just outlined, Streets Maintenance Section met the challenge of the downturn in the economy in the early 1980s through productivity improvement. The remainder of the Engineering Department did likewise. In recognition of this achievement Calgary was awarded "The National Award For Excellence In Productivity Improvement" by the Canadian Society for Industrial Engineering in 1986.

More specifically, today Streets Maintenance is providing levels of service equal to 1980 on a network which has grown by 19 percent. On average, this is being done with 18 percent fewer full-time equivalent staff years. The street-cleaning equipment fleet has been reduced by 27 percent, while the snow and ice control fleet has been modernized and increased by 12 percent.

SPECIFIC ANNUAL WORK PLANS

To this point in the paper most of the components of the general annual work plan have been described. What follows are examples of annual work plans for specific programs concerning street maintenance. Plans for snow and ice control, street cleaning, and asphaltic concrete repairs will be discussed.

Snow and Ice Control Plan

Snow and ice control (SNIC) plan is an annual $10 million endeavour. An inordinate snowfall of 23 cm in a 24-hour period in January 5-6, 1989 put the SNIC plan through a severe test. The test was passed successfully, although some dissatisfaction expressed regarding the level of service on residential streets.

Without a plan and adequate funding, there would have been a great deal more controversy surrounding the response to the snowstorm. Calgary has not experienced a severe winter since 1982. It is a credit to Calgary's city council; they permitted funding during this time to the 10-year average winter. Without such funding, preventive maintenance programs would likely have been sacrificed to pay for the unbudgeted cost in SNIC, or a budget over-run would have resulted.

In preparation for the 1988 Olympics, the snow and ice control policy was reviewed and an updated SNIC plan was produced. The plan is based on levels of service derived from council direction, provided in response to citizen concerns over the years.

The difficulty with any SNIC plan is establishing an adequate amount of labour, equipment, and material to deal with most winter conditions. During mild winters productive alternative work is hard to find, if staffing levels are too high; however, during a severe winter, staffing may be insufficient.

To deal with the input resources difficulty, Calgary has used Environment Canada statistics to determine the 10-year average of snowdays. A snowday is defined as a 24-hour period with more than a trace of snow. Figure 6 shows the distribution of snowdays over a 10-year period.

As with any average, it is sometimes hard to explain events which do not appear to follow the average. For the most part the 10-year average has been accepted. A further refinement of the snowday criterion is the distribution of budget funds over the winter months to carry out variance reporting. Figure 7 shows the monthly distribution of snowdays in Calgary.

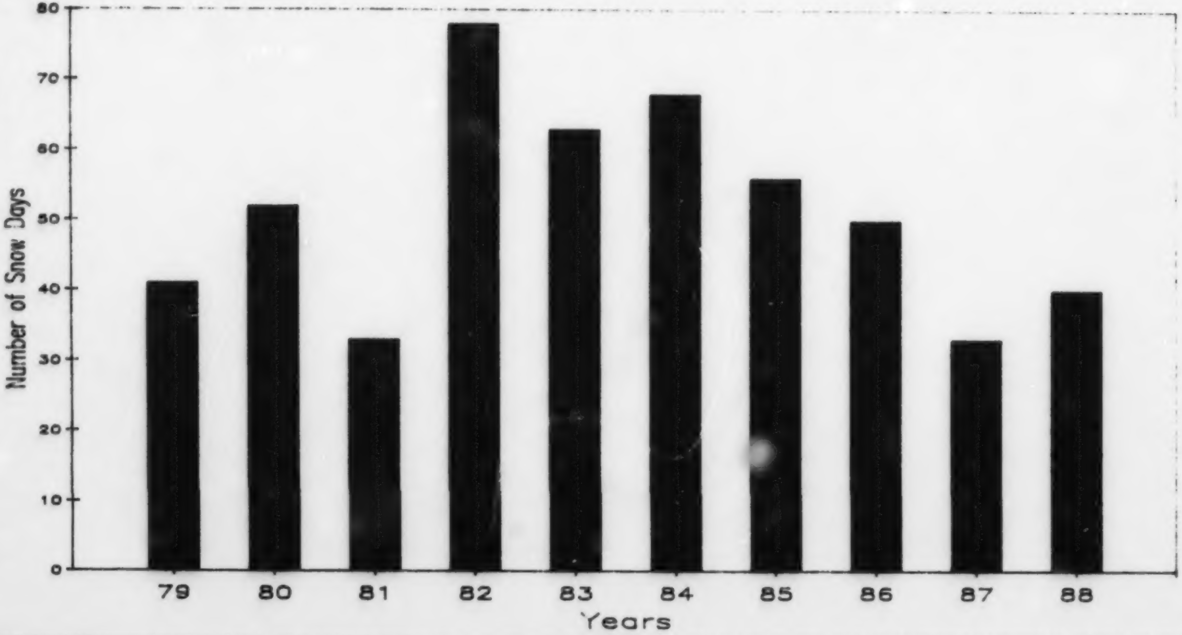
A key part of the plan contains sanding, salting, and plowing routes for every part of the city. The routes are prioritized on the basis of traffic volumes into four priorities: arterials, the central business district, and collectors are priority-1 and -2 routes. These are dealt with throughout a snowfall based on the principle that drivers can proceed slowly on residential streets and with relative ease on the arterials and collectors. Figure 8 is an example of priority-1 routes.

Indicators of efficiency and effectiveness for snow episodes need refinement and improvement. So much is going on during a snowstorm that crews are hard-pressed to fill out forms regarding results. But without information, analysis for improvement is impossible. Streets Maintenance is tackling this problem through automation.

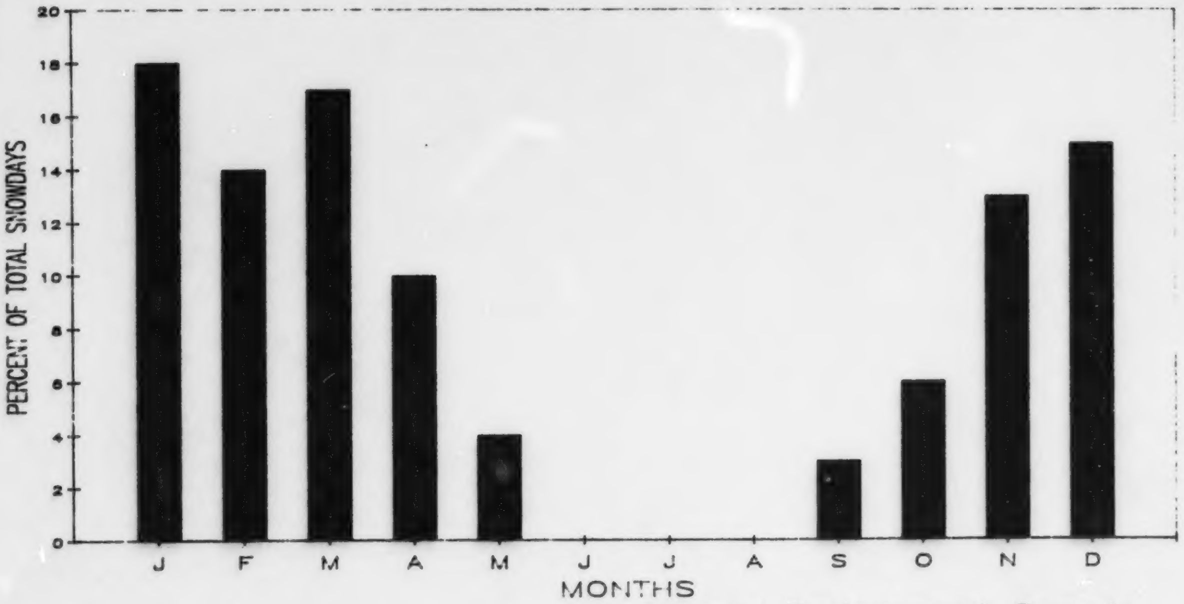
Days of Snow in Calgary

Extracted from Environment Canada Meteorological Summary

Figure 6



AVERAGE SNOWDAY DISTRIBUTION
25 Year Average (1963 - 1987)
Figure 7



• Source: Environment Canada

FIGURE 8

ZONE 5
SNOW AND ICE CONTROL
PRIORITY 1

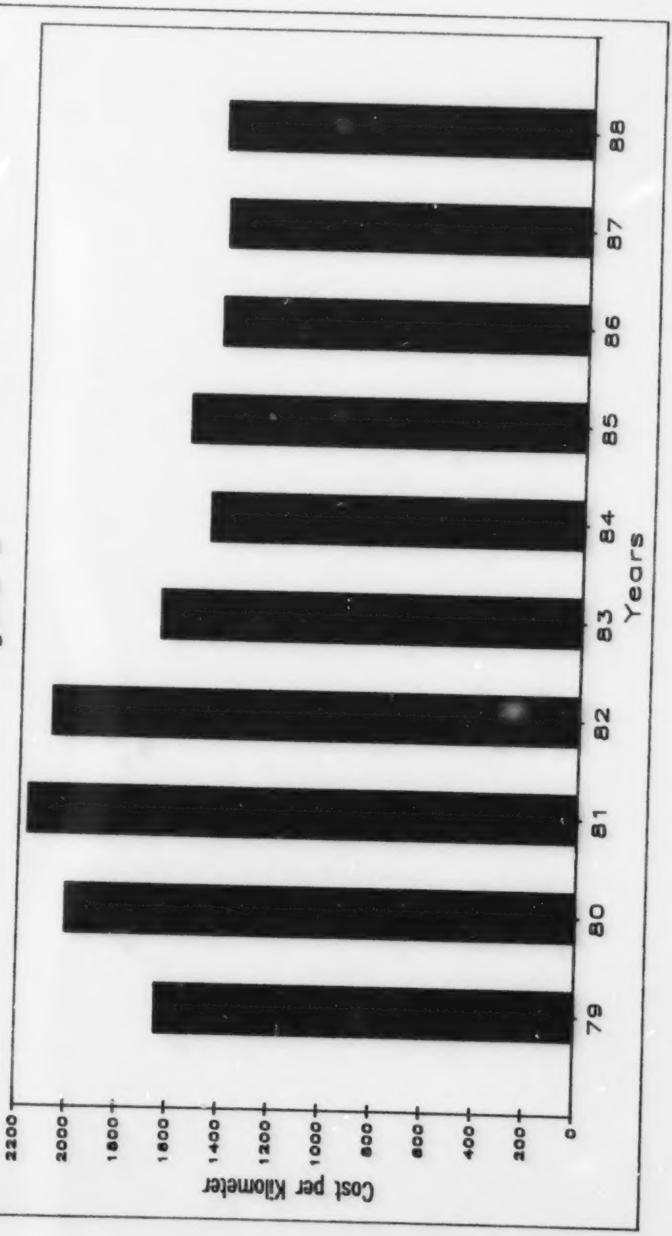
SEQUENCE	DESCRIPTION: Through sanding and salting.			REVISION:	REF.NO.
	ROUTE 1	RED	CALL No. 540	FEB. 1988	1
	LOCATION			LENGTH	
	ON	FROM	TO	Lineal km	Lane km
1	2 Street SW	26 Avenue SW	17 Avenue SW	0.91	3.01
2	5 Street SW	26 Avenue SW	17 Avenue SW	0.92	4.12
3	26 Avenue SW	4 Street SW	2 Street SW	0.33	0.55
4	4 Street SW	26 Avenue SW	17 Avenue SW	0.91	4.11
5	Elbow Drive	4 Street SW	Heritage Drive	12.26	21.61
6	Sifton Blvd	Elbow Drive	38 Avenue SW	1.10	3.50
7	38 Avenue SW	Sifton Blvd	14 Street SW	0.18	0.60
			TOTAL	16.61	37.50

KEY LOCATIONS: A.M. - BROOM BOX ON LANSDOWNE AVENUE
P.M. - BROOM BOX ON LANSDOWNE AVENUE

City of Calgary - Streets Maintenance

Street Cleaning Unit Cost in 1988 Dollars

Figure 9



At present, there are five locations in the city which continuously monitor surface and air temperature, precipitation, and salt content on the street surface. Sensors in the street surface transmit data through telephone lines to a computer in the SNIC operations centre. The information obtained is displayed continuously to be used for decision-making regarding response.

Street-Cleaning Plan

Most of the $4.2 million expended annually on street-cleaning relates to the removal of the sanding materials used during the winter. It is important then to control dust as a reduction of a health hazard. Finally, there is the matter of civic pride in maintaining a clean city.

The spring clean-up of winter sanding materials follows a plan which has a completion goal of July 15. The late date results from several budget cuts since 1982. The street-cleaning equipment fleet has been reduced to conform to the budget cuts.

Efficiency and effectiveness indicators are reliable for this program, hence it has been possible to moderate the effect of the cuts. During most years, the clean-up is completed by July 01. Figure 9 shows cost per km for the past 10 years.

When budget cuts have been necessary, senior administration staff and city council have followed the recommendation of Streets Maintenance staff as to where the cuts should occur. Street-cleaning has a lesser impact on public safety than other programs, hence the reduction in level of service regarding the date of completion is tolerable. A reduction in the cleanliness standard to reduce cost is an option, but this would be an imbalance between efficiency and effectiveness.

Asphaltic Concrete Repair Plan

The value of this program annually is $4.5 million. Also related to this program is the annual overlay program of $8,500,000. The asphalt repair plan allows for both corrective and preventive maintenance. Corrective maintenance responds to the need to fill potholes as an emergency.

The plan uses two computer-based management programs to develop the annual work plan: the Street Condition Survey and PAVER. The Street Condition Survey has been in operation since 1976, with an update completed in 1981. PAVER is an APWA pavement management system which has been in operation since 1984.

The survey is carried out each spring by zone foremen who receive refresher training and follow a guideline booklet. The data are entered on the form shown as Figures 10 and 11. The key feature of the annual street condition survey is that it identifies defects according to severity. The City's mainframe computer produces pre-printed work lists for each zone from the data gathered during the survey. Work is scheduled on the basis of "worst first".

It is intended that eventually PAVER and the Street Condition Survey programs will be integrated. This has been delayed because Alberta Transportation is developing a microcomputer-based municipal pavement management system to which we will switch from PAVER. In the meantime, PAVER is providing an overall measure of effectiveness which shows an improvement of 37 percent since 1984.

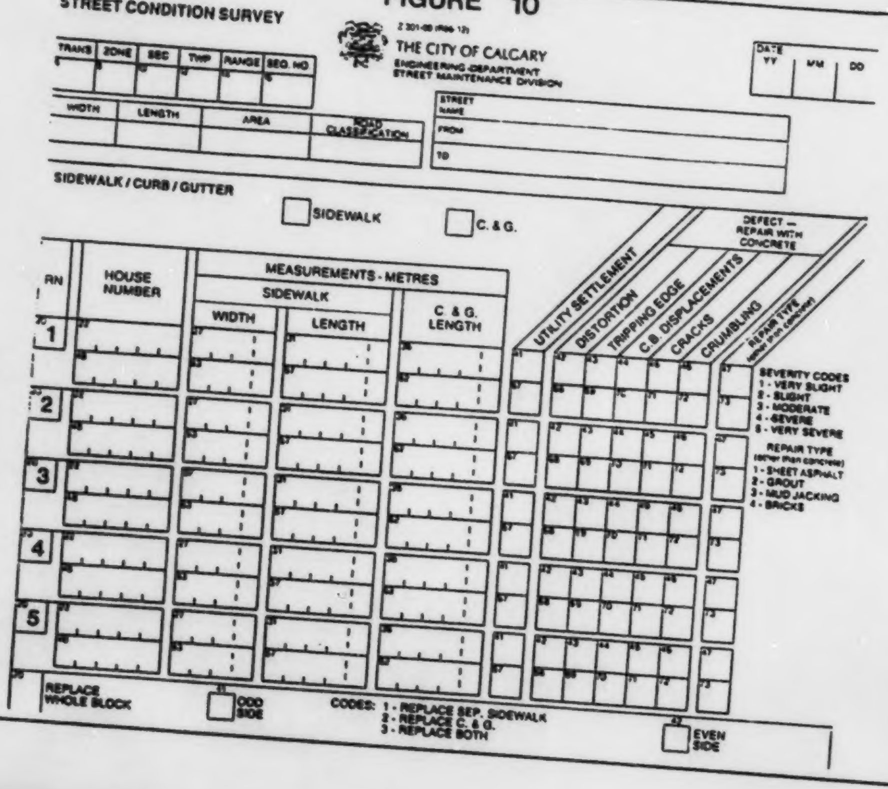
PAVER is also used to identify streets due for a surface overlay. Once these streets have been selected, additional non-destructive testing and evaluation is carried out. Coordination with Waterworks, Sewers, and other Utilities is completed, then the annual work plan for an overlay program is produced. The goal of having all streets exceed a PCI of 65 is being reached and there is a clear indication that the overlay program can be trimmed.

PRIORITIES

Municipal budgets throughout Canada are constrained by inflation combined with the reluctance to raise taxes. This reluctance is certainly prevalent in Calgary, since the economic recovery has been slower than expected. Productivity improvement has delayed cuts in service levels, hence preventive maintenance of infrastructure has not as yet been significantly affected.

Although the rate of inflation has moderated by comparison to the early 1980s, it continues to have an impact on the cost of input resources. The state of the economy makes careful planning of street maintenance work essential. All work has to be prioritized, since there is always more work to do than there are funds available to do the work.

FIGURE 10



STREET CONDITION SURVEY

Z 301-00 (Rev. 12)

THE CITY OF CALGARY
ENGINEERING DEPARTMENT
STREET MAINTENANCE DIVISION

DATE YY MM DD

TRANS ZONE SEC TWP RANGE SEG. NO

WIDTH LENGTH AREA ROAD CLASSIFICATION

STREET NAME
FROM
TO

SIDEWALK / CURB / GUTTER

☐ SIDEWALK ☐ C. & G.

RN | HOUSE NUMBER | MEASUREMENTS - METRES: SIDEWALK WIDTH, SIDEWALK LENGTH, C. & G. LENGTH | UTILITY SETTLEMENT | DISTORTION | TRIPPING EDGE | C.B. DISPLACEMENTS | CRACKS | CRUMBLING | REPAIR TYPE (other than concrete)

DEFECT — REPAIR WITH CONCRETE

1
2
3
4
5

SEVERITY CODES
1 - VERY SLIGHT
2 - SLIGHT
3 - MODERATE
4 - SEVERE
5 - VERY SEVERE

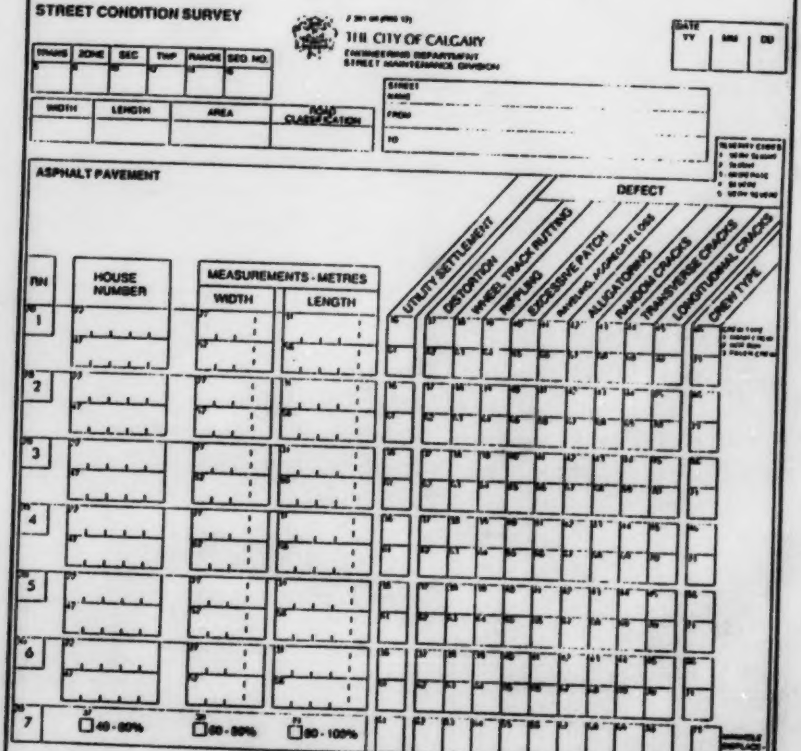
REPAIR TYPE (other than concrete)
1 - SHEET ASPHALT
2 - GROUT
3 - MUD JACKING
4 - BRICKS

REPLACE WHOLE BLOCK

☐ ODD SIDE

CODES: 1 - REPLACE SEP. SIDEWALK
2 - REPLACE C. & G.
3 - REPLACE BOTH

☐ EVEN SIDE



STREET CONDITION SURVEY

THE CITY OF CALGARY
ENGINEERING DEPARTMENT
STREET MAINTENANCE DIVISION

DATE YY MM DD

ZONE | SEC | TWP | RANGE | SEQ NO.

WIDTH | LENGTH | AREA | ROAD CLASSIFICATION

STREET NAME
FROM
TO

ASPHALT PAVEMENT

DEFECT

RN	HOUSE NUMBER	MEASUREMENTS - METRES WIDTH	MEASUREMENTS - METRES LENGTH	UTILITY SETTLEMENT	DISTORTION	WHEEL TRACK RUTTING	RIPPLING	EXCESSIVE PATCH	RAVELING, AGGREGATE LOSS	ALLIGATORING	RANDOM CRACKS	TRANSVERSE CRACKS	LONGITUDINAL CRACKS	CREW TYPE
1														
2														
3														
4														
5														
6														

7 ☐40 - 60% ☐60 - 80% ☐80 - 100%

FIGURE 11

In general terms, priorities are set on the basis of concern for public safety and repairing the "worst first". Concern for public safety, although paramount, has to be moderated by what is affordable. It would be extremely expensive to provide summer driving conditions on a 4280-km street system for the duration of winter.

The SNIC plan has an inventory of all locations which are to receive some degree of treatment during the winter. Arterial routes, treated as priority 1, are marked on maps; as are stop signs and trouble spots, which are treated as priority 4 on residential streets. Priority 1 is treated urgently, at high cost for overtime and contracted resources, if required. Priority 4 is done during the regular day-shift at much lower costs.

Every infrastructure work plan for a large city must have an inventory. Without an inventory, work will not be prioritized properly. Calgary has had an automated street inventory in place since 1976. The Street Condition Survey program is used to produce prioritized annual work lists for concrete and asphalt repairs. The PAVER system is used to prioritize streets for asphalt overlay in addition to providing feedback on the overall condition of Calgary streets.

CONCLUSION

This paper has attempted to provide an insight into the methods used to operate and to maintain Calgary streets. A combination of actions by both city council and the City's administration has resulted in prudent use of resources to maintain the infrastructure in satisfactory condition. There is very little funding flexibility left to continue a high level of preventive maintenance.

In the event that levels of service have to be cut, public safety will always pre-empt preventive maintenance. The cost of corrective maintenance, such as pothole repairs or emergency repairs to concrete, increases very quickly. Of necessity, the more unplanned the work, the more the costs go up. A cycle is set up which ultimately results in much higher costs for infrastructure maintenance. A decision by the two senior levels of government to provide additional funding for infrastructure would be timely indeed.

THE ROLE OF RECYCLING STRATEGIES IN THE REHABILITATION OF URBAN PAVEMENTS

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ABSTRACT

Since the first two projects in 1982, initiated primarily because of actual and projected increases in asphalt cement prices, there have been significant benefits from the use of asphalt pavement recycling on rural highways in Alberta. During the ensuing 7-year period, Alberta Transportation & Utilities have reclaimed nearly 900,000 tonnes of asphaltic pavement material (RAP), with most of this used in the production of over 1.45 million tonnes of recycled asphaltic concrete pavement (RACP). Estimated savings are approximately $7 million for this period.

Cold-milling techniques have been largely used for reclaiming, and dryer-drum plants for hot-mix production. Since pavement recycling problems are different in the urban environment, appropriate strategies need to be selected to implement recycling in the rehabilitation of urban pavements. Constraints in project selection, various possible recycling methods, and anticipated benefits are discussed, and some examples of asphalt pavement recycling in Alberta's cities are presented.

RÉSUMÉ

Depuis la réalisation des deux premiers projets du genre en 1982, amorcés essentiellement en raison des augmentations autant réelles que prévues du prix du bitume asphaltique, le recyclage du revêtement d'asphalte des autoroutes rurales de l'Alberta procure beaucoup d'avantages. En effet, au cours des sept années suivantes, le Ministère des Transports et des services publics de l'Alberta a pu ainsi récupérer près de 900,000 tonnes de revêtement asphaltique et s'en servir en grande partie pour produire près de 1,45 million de tonnes de béton asphaltique recyclé. Pour cette période, les économies s'estiment à environ 7 millions de dollars.

La technique de reprofilage à froid a été largement adoptée pour la récupération, et les centrales à tambours sécheurs pour la production d'enrobés à chaud. Come les problèmes de recyclage du revêtement en dur diffèrent en milieu urbain, le choix doit se porter sur des stratégies adaptées en vue de donner suite à la notion de recyclage dans la réfection des revêtement de chaussées en milieu urbain. L'exposé établit les restrictions touchant le choix des projets, les diverses méthodes possibles de recyclage et les avantages escomptés, en plus d'illustrer certains exemples de recyclage du revêtement d'asphalte dans des villes de l'Alberta.

INTRODUCTION

Asphalt pavement recycling has been a subject of particular interest since the mid-1970s when the price of crude oil, and consequently asphalt cement, experienced sharp increases worldwide. In 1981, it was determined that the cost index for asphalt cement supplied to Alberta Transportation had increased over six times that of 1971. Although the costs at that time were in the order of $230/tonne, many forecasts were being made that prices could rise to $500 or more in the next decade. This was the scene at the time when Alberta Transportation began to investigate the use of recycled asphalt for use on the provincial highway system.

An investigation (Anderson, 1981, 1982) concluded in part that asphalt pavement recycling is a cost-effective alternative and that cold-milling of existing pavements combined with central hot-mix recycling would be the most feasible method of recycling for the primary highway system in Alberta. This paper will review some of the highlights of the work on rural highways in Alberta, together with examples of asphalt pavement recycling in some Alberta cities in order to focus on the possible role of these techniques in the rehabilitation of urban pavements.

EXTENT OF RECYCLING ON RURAL HIGHWAYS IN ALBERTA

Since the first two projects in 1982, there has been a rapid increase in the number of projects designed and completed. By 1985, a total of 16 such projects was reported (McMillan and Palsat, 1985). From data available to the end of 1987, a total of 42 projects were summarized. During this 6-year period, Alberta Transportation & Utilities (AT&U) reclaimed over 700,000 tonnes of asphalt pavement material (RAP). Most of this reclaimed material has been used in the production of over 1.2 million tonnes of recycled asphalt concrete pavement (RACP) in central hot-mix plants of the dryer-drum type. Inclusion of 1988 information raises these totals to 900,000 tonnes of RAP and 1.45 million tonnes of RACP for the 7-year period.

Figure 1 shows graphically the yearly amounts of reclaiming and recycling by AT&U, while Figure 2 presents cumulative quantities of RAP and RACP over this time period. Projection of the current rate would indicate some 100,000 tonnes of RAP and in excess of 200,000 tonnes of RACP. With the total production of hot-mix asphaltic concrete (ACP) ranging from 3 million to 4.7 million tonnes annually, the RACP market share is still only 3 to 6 percent of the total.

Actual projects planned for 1989 yield estimates of over 300,000 tonnes of RAP and 600,000 tonnes of RACP, a significant increase over previous years. It would seem that recycling has been widely accepted throughout the province on the rural highway system.

BENEFITS OF RECYCLING

The three major potential benefits that have been reported for asphalt recycling are cost reductions, energy savings, and conservation of natural resources (LaHue, 1980). Other benefits concerning curb and manhole elevations, maintaining overhead structure clearances, and the like have been suggested but are usually of less importance.

Conservation of natural resources is the simplest of the benefits to quantify since it involves the reclaimed materials only. The total amount of RAP stockpiled during the 6-year period ending in 1987 was discounted by an assumed 10-percent loss and the amount of asphalt cement to yield an amount of 620 000 tonnes of crushed aggregate. The net amount of RAP was assumed to contain 5.5 percent by total mass, resulting in some 36,000 tonnes of asphalt cement.

The salvage value of the RAP was considered to equal the value of the aggregate and asphalt cement less the cost to remove and haul these materials to a stockpile and any costs necessary to prepare them for the recycling process. This method has been used by others for estimating salvage value of reclaimed materials (Smith, 1980). The salvage value of the aggregate, using a unit value of $2.65/tonne including royalties, was approximately $1.6 million. Asphalt cement was considered at $250/tonne, nearly the average value for the period from 1982 to 1987, giving a value of $9 million. The cost of reclaiming and hauling to a stockpile was estimated at $9.00/tonne for a total of $6.6 million, resulting in a net salvage value of $4.1 million for the RAP materials.

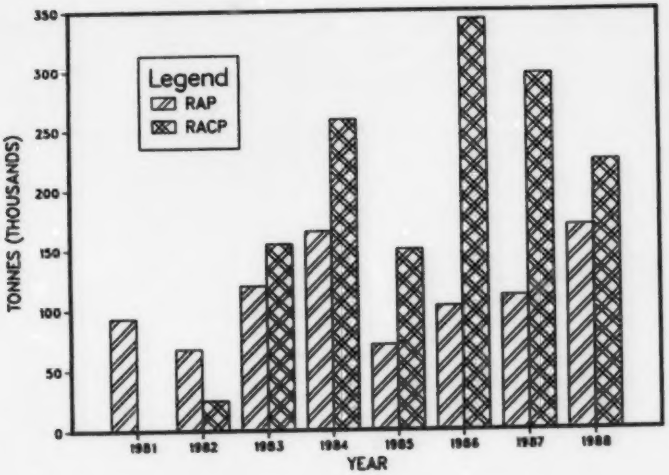

Figure 1. Reclaiming and Recycling in Alberta

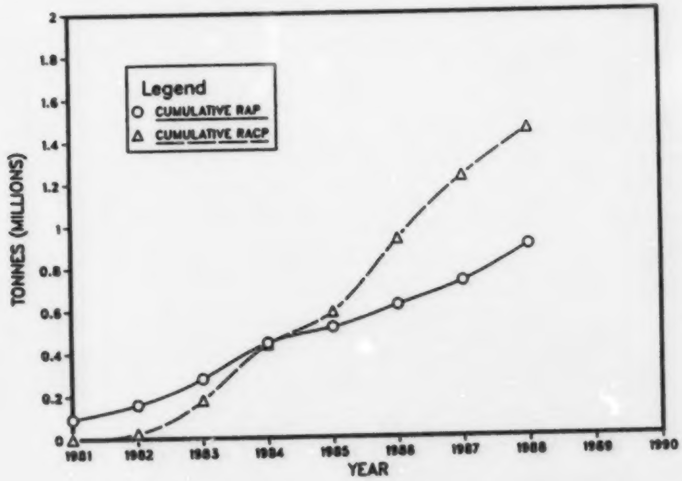

Figure 2. Cumulative Reclaiming and Recycling versus Time

The savings due to recycling are even greater when the difference between the bid price for mixing and placing ACP, compared to RACP, is considered. This difference averaged $1.51/tonne less for RACP than for the conventional ACP. While this is an unexpected advantage in favour of recycling, it resulted from actual bid prices over the 7-year period. Possible differences may be speculated as due to reduced crushing costs for the aggregate in the RACP. Whatever the reason, this difference represents a saving of $1.85 million for the RACP placed. The combined estimated savings from 1982 through 1987 are in the order of $6 million, or approximately $1 million annually. Applying this amount for the 7-year period, including 1988, would result in estimated savings of $7 million.

Despite the generally lower asphalt cement prices in 1988, in the order of $170/tonne, alternatively bid projects on at least two occasions have resulted in the reclaiming and recycling procedure to be that of the least cost.

In addition to the described economic benefits resulting from savings in material costs, there have been significantly large reductions in rehabilitation costs due to alternative strategies made possible by cold-milling and recycling. An example of this is the selective treatment of rutted pavements by removing the deformed pavement, say, of a 4-lane, divided highway, in the outside lane and to replace this lane with recycled or conventional material. This procedure eliminates the need for a full-width overlay, if additional strengthening is not necessary. This method would at least defer the need for an overlay, resulting in substantial savings yet to be quantified.

One can only speculate about the savings that might have accrued because of recycling, if the cost of asphalt cement had continued to rise beyond 1985 when it reached the $300/tonne plateau. Drops in world oil prices resulted in a significant lowering of asphalt cement prices; however, all indications are that this is only a temporary situation.

Experience gained in the design and construction of RAP has resulted in benefits to the owner, i.e., the taxpayer, and to the industry as a whole. The contracting industry has the necessary equipment and expertise to undertake this type of work successfully, which was considered experimental merely a decade or so ago. Further improvements can be anticipated as the opportunities become available to undertake various rehabilitation projects on urban pavements.

URBAN RECYCLING STRATEGIES

Pavement recycling problems have been shown to be different in the urban environment from those in rural areas (Vicelja,1980). In cities, the size and magnitude of the projects are generally smaller in scope. Also, there are many more physical constraints, such as curbs and gutters, catch basins, driveways, cross gutters, median curbs, manholes, etc., which influence the design and construction phases.

Project location often limits the techniques available when working in a central business district, or in an industrial or residential area. Traffic control considerations are a concern as are dust and noise levels. Emission levels during hot-mix operations are usually more subject to public scrutiny in highly populated areas, and therefore available techniques must be implemented to alleviate such public concerns. A task force that studied this problem specifically concluded that the technology for successful recycling does exist (Millions *et al.*,1985).

Categorization of recycling procedures within a framework developed by Synthesis panel members (NCHRP Synthesis 54, 1978) is shown in Figure 3. The following definitions are based on these suggestions.

Surface Recycling. Reworking of the surface of a pavement to a depth of less than about 25 mm by heater-planer, heater-scarifier, hot-milling, cold-planing, or cold-milling devices. This operation is a continuous, single-pass, multi-step process that may require the use of new materials, including aggregate, modifiers, or mixtures.

In-Place Surface and Base Recycling. In-place pulverization to a depth greater than about 25 mm, followed by reshaping or compaction. This operation may be performed with or without the addition of a stabilizer.

Central-Plant Recycling. Scarification of the pavement material, removal of the pavement from the roadway prior to or after pulverization, processing of material with or without the addition of a stabilizer or modifier, and lay-down and compaction to desired grade. This operation may require the addition of heat, depending on the type of material recycled and the stabilizer used.

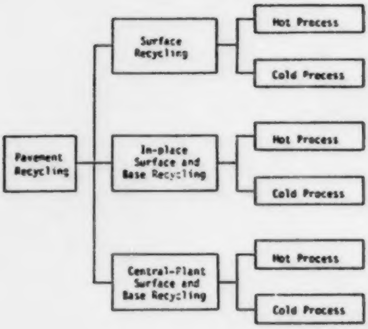
Pavement Recycling
Surface Recycling
In-place Surface and Base Recycling
Central-Plant Surface and Base Recycling
Hot Process
Cold Process
Hot Process
Cold Process
Hot Process
Cold Process

FIGURE 3: Categorization of Recycling Approaches Based on Recycling Procedures (Source: NCHRP, 1978).

Equipment and procedures have further developed since the invention of these definitions some 10 years ago. For example, the Asphalt Recycling and Reclaiming Association (ARRA) has technical committees that deal specifically with each major process or procedure. These committees and brief definitions as used by this organization are as follows:

Cold Planing. Cold-planing is the controlled cold-milling of pavement to restore the surface to a specified profile. Bumps, ruts, and other surface irregularities are removed, leaving a uniformly textured surface. The resulting textured pavement can be used immediately as a driving surface, or it can be overlaid with a minimum of material.

Cold In-Place Recycling. Cold in-place recycling is a road reconstruction technique that reuses the existing pavement structure, including, in some cases, the underlying, untreated base material. All work takes place on the grade and requires no transport of material.

Full-Depth Reclamation/Stabilization. Full-depth reclamation/stabilization is a reclamation technique in which the full flexible pavement section and a predetermined portion of the underlying materials are uniformly crushed, pulverized, or blended, resulting in a stabilized base course. Further stabilization may be obtained through the use of available additives. This reconstruction technique requires a wearing surface of a thickness that must be determined by an analysis of the traffic data.

Hot In-Place Recycling. Hot in-place recycling is an on-site, in-place method that rehabilitates deteriorated bituminous pavements and thereby minimizes the use of new materials. This process may be performed as either a single (1-phase) operation that monolithically recombines the restored pavement with virgin material, or as a 2-pass operation, wherein the restored material is recompacted. The application of the new wearing surface then follows a prescribed interim period that separates the process into two distinct phases.

Hot Recycling. Hot recycling is a process whereby hot-mix producers can recycle asphalt cement by using relatively inexpensive additions to existing plants. The mixer heat transfer method, where RAP materials are heated through conduction by super-heated new aggregates, is the most acceptable method for hot recycling. This process can take place either in a batch plant or in a drum-mix plant. The techniques vary significantly with the equipment used.

ARRA has produced several guideline specifications, which are available through the Association, and is in the process of reviewing and developing additional guideline specifications for full-depth reclamation/stabilization and hot in-place recycling.

The October issue of the Roads & Bridges magazine annually contains a special report on asphalt reclaiming and recycling. A summary of basic specifications for in-plant hot recycling for 50 states is available (ARRA '87).

IMPLEMENTATION OF ASPHALT RECYCLING

A major concern in implementation of asphalt recycling of urban pavement is the uniformity (or rather its lack) in the RAP. Despite the high probability that a non-uniform RAP supply could be expected, the effects of this variability could be minimized by using low percentages of RAP in the hot-mix. Successful results have been obtained with ratios as low as 15 to 25 percent.

Emission levels during hot-mix plant operations are usually more subject to public scrutiny in highly populated areas. This is applicable to conventional as well as recycling plants; however, the task force that studied this problem specifically concluded that the technology for successful recycling does exist (Millions, 1985).

Ownership of the RAP and subsequent use or disposal of the material is an important factor in making the decision whether to consider recycling for pavement rehabilitation. This and many other factors were presented by Smith in 1980.

Concerns may also be expressed by some regarding the suitability of recycled mixes for heavy-trafficked pavements. Numerous studies have reported that recycled mixes, if properly designed and constructed, have performed as well as, or even better than, conventional mixes. Early work done in Japan has indicated that mixes with RAP at rates of 20, 30, and 40 percent were superior to new asphalt mixtures alone (Mise *et al.*, 1980). Detailed evaluation of recycled mixtures in our studies have shown that they are more resistant to permanent deformation than comparable virgin mixes (Hadipour, 1987; McMillan and Anderson, 1988).

Many other considerations that will depend on each jurisdiction will have to be made; but as many have reported, it seems reasonable to conclude that recycling procedures are an acceptable alternative for urban as well as rural pavement rehabilitation. Some additional engineering effort will be required; however, the potential benefits should easily justify the additional effort required.

EXAMPLES OF ASPHALT PAVEMENT RECYCLING IN ALBERTA CITIES

City of Edmonton

The heater scarification process has been used for asphalt pavement rehabilitation programs since 1975, when the first section was treated with this surface recycling technique. Because of the apparent reduction in reflective cracking on the overlay, an additional 300,000 m^2 were treated in 1977. During the 1978 and 1979 construction seasons, approximately 250,000 m^2 were heater-scarified and the general procedures were standardized. In 1981, additional test sections were constructed with the intent to monitor performance, particularly with regard to reflective cracking.

A number of evaluation reports have been prepared by the then Roadway Operations, Engineering Department, (City of Edmonton, 1978,1980) and summarized (Hussain, 1985). Comparisons of a 46-mm conventional overlay with 32-mm overlay used in conjunction with 14-mm heater scarification were expected to have the same effective thickness, but with considerable savings in aggregate and asphalt cement. The additional cost of using a rejuvenation agent at \$0.16/m^2 could not be justified on the basis of observations after 2 years of service.

Some additional heater scarification work was done in 1986; however, no major contracts have been awarded recently.

In 1987, a rehabilitation program on Capilano Freeway involved cold-milling to remove a rutted surface with RAP being used in two ratios of 20/80 and 30/70 in central-plant hot recycling. Hot-mix was produced in a Boeing-type drum-mix plant equipped with a pyrocone heat shield. Approximately 1000 tonnes of recycled mix was placed on experimental sections on Old Fort Road which will be monitored together with comparative sections of conventional mixes. Additional recycled mix was placed on other roadways as part of this contract but not monitored.

Low-temperature tensile tests conducted on compacted specimens from these mixtures showed no significant differences in failure stress, strain, or stiffness over a temperature range of 0°C to -30°C. This result is similar to that found in earlier work (Hadipour, 1987) with mixtures containing low ratios of RAP to virgin aggregate.

Recycling is considered to be a feasible rehabilitation procedure and is planned to be a bid alternative on at least one City of Edmonton project in 1989.

City of Lethbridge

The City of Lethbridge had been experiencing premature rutting on asphalt pavements with both new construction and overlays, so EBA Engineering Consultants Ltd. was commissioned to study the cause and to make definitive recommendations to mitigate its occurrence in the future (Hogeweide and MacDonald, 1988). An extensive laboratory testing program was undertaken and comparative rankings were made for various mix types. In addition to conventional Marshall and Hveem tests on compacted specimens, creep and repeated load triaxial tests were performed. Reclaim mixes, using both conventional virgin asphalt and polymer-modified asphalt, showed less deformation than the standard mix and were comparable to the mix with larger topsize aggregate.

In order to verify the anticipated improved performance of mixes, a series of test sections were constructed in the city in June, 1988. Since the zone of disturbance had been observed to be in the order of 70 mm, it was concluded that this should be the standard depth for cold-milling of the rutted pavement for the test sections going approximately 30 m back from the stop line of the intersections.

Two mixes contained 30 percent RAP, one with Husky PMA4 binder and the other with 200-300 penetration grade asphalt cement. A batch-type (4000-lb) hot-mix plant was modified to accept the RAP into one of the hot-aggregate storage bins. The conveyor belt was loaded by a front-end loader, with the batch weights being controlled manually by the plant operator. Conventional placing and compacting equipment was used with densities in the order of 98 to 99 percent of 75 blow Marshall being achieved.

Construction of these test sections of recycled and other mix types was accomplished successfully with a minimum of delay and equipment modification. Monitoring of these and later constructed test sections is continuing.

City of Calgary

As with most municipalities, surface overlays have been extensively used when improvements are necessary; however, increased pavement thickness cannot be tolerated in many instances due to existing curb and gutter profiles. It is common to remove a thin layer of the surface through a cold-milling process or through a heater scarifier process. Although both techniques have been used and reported on by the City of Calgary, road cold-planing has been the most common practice. A number of surface overlay studies have been undertaken, including various types of fillers and additives. Recent studies have considered polymer-modified asphalts with the hopes of improved performance and economic benefits (Rodier and Kitchen, 1988).

An existing intersection that has displayed significant rutting and shoving has been selected for planing to a depth of at least 150 mm. A 100-mm base course of 32-mm top-size aggregate polymer-modified asphalt mix followed by a 50-mm surface overlay was planned.

Because of the favourable aggregate supply generally in the Calgary area, hot-mix recycling has not been used as a rehabilitation strategy to date, although the RAP from cold-milling has been used as base aggregate or other suitable ways.

SUMMARY AND CONCLUSIONS

Recycling of asphalt pavements has been increasing rapidly over the past 7 years in Alberta and is now widely accepted on the rural highway system as a feasible rehabilitation strategy. Approximately 900,000 tonnes of RAP and 1.45 million tonnes of RACP have been processed. The vast majority of the reclaiming has been done by cold-milling and all the central-plant hot-mix is produced with drum-mix plants. Estimated savings are in the order of $7 million, not counting potential benefits from more cost-effective design strategies.

Recycling procedures have not been extensively used for urban pavements in Alberta. Surface recycling with a heater scarifier has been used as early as 1975, but has not been continued as a widely accepted process. This may have been due to limited depth capabilities of the equipment available; however, improved equipment and procedures may change this. Recent experiences with central-plant hot-mix using reclaimed asphalt materials from cold-milling operations has been promising and it appears that more of this type of work will be done in Alberta's cities.

In view of the satisfactory performance to date and the great potential for using this cost-effective method, asphalt pavement recycling should be considered feasible alternative for the rehabilitation of urban pavements.

ACKNOWLEDGMENTS

Financial assistance, provided by both Alberta Transportation and Utilities and the Natural Sciences and Engineering Research Council (NSERC) of Canada, through research contracts and grants has supported the research and development reported.

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SENIOR GOVERNMENTS - QUO VADIS?

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ABSTRACT

An overview of the infrastructure situation in the City of Winnipeg, focussing on the public perceptions of the FCM's infrastructure program will be presented. The provincial role in infrastructure financing and arguments in favour of the federal participation will be discussed.

RÉSUMÉ

Après avoir jeté un coup d'oeil sur l'état actuel de l'infrastructure de Winnipeg, en s'attardant sur la façon dont le public perçoit le programme des infrastructures de la FCM, on discutera du rôle du gouvernement provincial face au financement des infrastructures et des raisons militant en faveur de la participation fédérale.

Urban infrastructure - our streets, bridges, sidewalks, water and sewer systems - form the basic framework and foundation of our cities. Indeed, the health and well-being of Canadians depend on the condition of the basic services it provides. The quality of life we enjoy, our economic prosperity, is linked to the quality of our roads, water, bridges, streets, and highways.

The continued erosion of our physical infrastructure facilities means that we will suffer a loss in the quality of life. As municipal politicians and officials, it is incumbent upon us to work toward a solution to this menacing problem.

The Federation of Canadian Municipalities' executive and members who have worked hard to raise the profile of this issue, should be congratulated for hosting conferences such as the one we are at today. Only through greater public awareness and education can we hope to alert the Canadian public and other governments to mobilize our collective efforts to overcome this monumental task. The FCM is playing a pivotal role in this awareness campaign.

The roots of our present-day problems, of course, go back to the period just after World War II. At that time, there was a great deal of rapid growth in the economy. Post-war rebuilding, maintenance, and expansion of infrastructure facilities were completed to meet the needs of a dynamic, growing, and increasingly urban society in Canada. Now, our infrastructure systems have reached the end of their natural life-span.

Over the last decade, the cost of maintaining and upgrading our existing infrastructure systems began to rise just at the time when municipal revenues began to fall to levels below the inflation rate.

At the same time, the emphasis on spending by all levels of government in the 1970s and early 1980s shifted rather dramatically to cultural or recreational programs. This, of course, is all well and good, but our streets, bridges, sewers and water facilities became less attractive investments - a concern in distant second place. The City of Winnipeg is no exception. Some of the $30 million which Winnipeg contributed to the Core Area Initiative came out of budgets that had originally been earmarked for bridges and streets. The revenue at the municipal government level, therefore, simply was not there to undertake routine maintenance, repair, and replacement of our physical infrastructure. Our cities' tax base was not (and still is not) growing fast enough to provide for repairs and renewal of these facilities.

Add to this problem the fact that provincial governments were no longer increasing - and were often cutting back - their grants to municipalities and it is easy to see how our problems arose. Also, provincial governments, over the years, have tended to shift responsibility for providing urban facilities and service (e.g., welfare and ambulance services) without providing a corresponding shift in revenues to help finance these programs.

In addition to the provinces shifting responsibility for programs to municipalities, here in Manitoba, the Province now has begun to impose additional requirements on the City of Winnipeg which will force the City to spend several millions of dollars. For example, the provincial government recently passed legislation upgrading weight restrictions for transfer trucks on our highways. These regulations apply to City of

Winnipeg streets. There will be added costs in new streets and bridges, renovations, and renewals on existing streets and bridges resulting from heavier trucks using our streets. These expenditures were imposed without consultation, they place a great financial burden on the City and further inhibit our ability to direct our already limited resources to priority projects such as infrastructure renewal.

Furthermore, changes to the Environment Act, again made without adequate consultation, require the City to dry its sewage sludge. To build the facilities will cost the City $26 million and $2 to $3 million a year to operate.

The point to be made here is that the provincial legislation or changes to regulations do not provide for corresponding funding assistance, and given the huge capital and on-going costs involved in complying, the City's reconstruction priorities take a back seat to the Province's demands. One could argue that some financial relief should be forthcoming to help alleviate the huge capital outlays and annual costs thrust upon the City to meet provincial priorities.

These trends further reduce Winnipeg's ability to deal with the rising cost of infrastructure renewal and replacement. Every urban centre in Canada has come face to face with this unfortunate trend. Like all municipalities, Winnipeg has faced the all too familiar pressure of a largely static revenue base, a shift to cultural and recreational programs, and shrinking provincial transfers - all of which have occurred at the expense of maintaining adequate expenditures on our physical infrastructure. Over the past decade, the cost of upgrading or replacing these facilities has continued to increase unabated at a rate much faster than the municipalities' ability to pay for them. A look at the magnitude of necessary expenditures in Winnipeg reveals a common picture faced by all urban centres today.

Let me provide you with a thumb-nail sketch of the estimated cost of maintaining and replacing worn infrastructure facilities in Winnipeg. For instance, we estimate that the cost of maintaining and repairing our regional streets is $281.2 million over the next 10 years. Proposed expenditures, over the same period, will reach $118.6 million. That is a shortfall of over $162 million. Replacing bridges and regional streets that have reached the end of their life-span is estimated to cost $256.1 million. The City's expenditures, over the next 10 years, will only reach $168.5 million. Again, another major shortfall. Similar, massive expenditures beyond the financial capacity of the City of Winnipeg are required to maintain Winnipeg's district and collector streets. Some

$200 million is required to repair and upgrade district and collector streets. The City, however, has resources to cover $104 million over the next 10 years, leaving a $96 million shortfall. Also, recent estimates indicate it will cost the City of Winnipeg $1 billion to repair and fully separate its combined sewer system - a cost which is completely beyond the capacity of the City.

These figures, when taken together, graphically illustrate the gap between necessary expenditures and the ability to pay. So Winnipeg, like urban centres all across Canada, is facing a serious decline in its basic infrastructure.

The FCM has played a central role in evaluating the extent of infrastructure deterioration across Canada and, equally important, the association has provided what I believe to be a viable and reasonable long-term solution. In 1983, the FCM addressed this issue and went on to establish a task force on municipal infrastructure chaired by the then Mayor of Vancouver, Michael Harcourt. The findings of the task force, as we all know, were simply staggering. But there are no doubts about the accuracy of the price tag placed on fully upgrading our country's physical infrastructure systems - $12 billion was the estimated cost outlined in this landmark study. Since this study, the cost of renewal is now often quoted at $15 billion.

The FCM study is central to the issue of physical infrastructure renewal in Canada because it has quantified the extent of our infrastructure problems. It has meticulously surveyed the present-day conditions across Canada and, in blunt but realistic terms, has said how much it will cost Canadians to fix the problem.

So what is the solution to our infrastructure needs? The answer simply put is: money... lots of money.

Everyone in this room knows full well that our municipalities are more than willing to do their part in helping to solve the formidable problem facing our cities. But we are also painfully aware that a city's tax base cannot realistically be expected to finance the entire cost of infrastructure renewal. We cannot do it alone.

The solution, as the FCM has advocated, is for the three levels of government to work together constructively and to find ways to meet this urgent and increasingly unmanageable problem. All three levels of government must pool their resources and dovetail their various programs to provide maximum effect. Unfortunately, the pleas made by the FCM and other municipal governments has largely fallen upon deaf ears.

While several provincial governments have agreed in principle or muttered support for a tri-level approach to solve this mushrooming problem, the federal government has expressed no interest in participating. It has offered vague musings about infrastructure and municipalities being a provincial responsibility, hence Ottawa cannot and will not step on the provinces' toes. It also argues that deficit reduction is its main order of business, so it cannot afford to participate in a tri-level funding agreement that would cost it an estimated $5 billion. The provinces are willing to cooperate and participate, or so they say; but they, in turn, argue that they cannot afford to pick up all remaining costs. They want Ottawa to contribute to the solution.

The solution, as the FCM study has advocated - and I agree - is for a tri-level funding arrangement. By spreading the cost between the three levels of government, say $5 billion for each level over a number of years, the cost becomes manageable for each level of government. But for the federal government to agree to this proposal, it must begin to realize that its participation, as equal partner with other levels of government, would not only solve our country's infrastructure problems, but would provide a tremendous boost to the Canadian economy. The FCM study estimated that between 45,000 and 60,000 direct jobs could be created - that's new jobs - over each of 5 years, if a tri-lateral funding mechanism could be put into place.

In addition, the report estimated that the program, at the very least, would pay for itself. Indeed, the federal government could stand to gain for participating in the program, particularly when one looks at the spin-off from this increased economic activity. The cycle of benefits are obvious: construction creates jobs, materials purchases, salaries, and tax revenue. The federal government also would forgo paying unemployment insurance and it would gain revenue from income tax, sales tax, and other sources - as would the provincial governments. All of this means a much-needed shot in the arm for our economy. The solution is not and should not be seen as a way to bail out our municipalities. The benefits to each level government are real and quite significant.

In spite of Ottawa's repeated refusals to participate in this vital initiative, I still remain optimistic. I believe that we will forge a consensus between the three levels of government, and eventually we will begin to solve this problem. Indeed, some very recent signs are promising. Just recently, following the federal election last fall, Deputy Prime Minister Don Mazankowski indicated he is willing to sit down and talk about infrastructure renewal with the provinces and municipalities. I find this encouraging. I am also cautiously optimistic.

To begin with, the federal government must begin to realize that it has a critical role to play in this area; second, the public profile of the issue must be increased; and third, while the senior governments are getting their act together, municipalities must continue to make infrastructure renewal a top priority.

Let me elaborate on each point for a moment. First, federal participation in this initiative should not be seen by it as an infringement on provincial territory. Rather, Ottawa should view its participation as a way to promote economic activity, as an investment in our urban centres, and as a job creation activity. If Ottawa sees clear benefits, then it will act. We must work at convincing Ottawa that participating in a tri-level agreement is in its own best interest. That is a political benefit.

Second, the public profile of this issue is, at best, low; or at worst, non-existent. The public is genuinely unaware of the seriousness of our urban infrastructure problems. Indeed it does not see infrastructure as a priority issue. This ignorance of the magnitude of the issue can be extended to the media. This makes the job of selling the idea of the problem - and the solution - much more difficult.

Public works, by and large, are invisible and therein lies the problem. Infrastructure is largely taken for granted by all of us. People expect smooth streets, they expect pot-hole-free roads, they expect safe bridges, and they expect evenly constructed sidewalks. When people turn on their taps, they expect cleans, fresh water. Unless there is a major breakdown of these facilities - sudden pot-holes, a watermain break, or back-up of a combined sewer into residential basements - the public and media do not think about our physical infrastructure. And when there is a breakdown, the public is only remotely aware of an infrastructure problem - and then only until the problem is fixed. The major issue may not be thought of again, unless a councillor suggests more money is needed to fix the problem. The public backlash and media condemnation usually make a councillor back down.

Third, while we wait for the provincial and the federal governments to get their act together, municipal governments should not forget the fact that they have a prime responsibility for the upkeep and replacement of their physical infrastructure systems. Infrastructure renewal is and must continue to be a high priority for our municipalities. We must plan and provide, as best we can, for the ongoing renewal and replacement of physical infrastructure.

Municipal governments and effective associates like the FCM must continue to press our provincial and federal governments into action. Increased publicity and greater public awareness of the problem should serve to increase the political pressure on senior governments. We must continue to press for cooperative action until the task is done.

Finally, let me say that the sooner we arrive at a funding agreement with senior governments, along the lines I have described, the less costly will be the repairs. A dollar spent today will offset the need to spend $4 or $5 tomorrow. All governments must face up to their collective responsibilities to put an end to the rot in our infrastructure and avoid a potential crisis.

In conclusion, I want to leave you with the following message. All of us probably will recall the oil filter commercial which was seen so frequently on television a few years back. In that commercial, the auto mechanic says as he is holding an oil filter, "You can pay me now, or you can pay me later". His message, of course, was that if you do not take preventive maintenance measures today, you will pay the much higher price for neglect tomorrow.

If I were to put together a commercial selling the advantages of beginning our urban infrastructure renewal program today, my message would be this: "You had better pay me now, because if you wait until tomorrow, it will be too late!".

OVERVIEW OF THE SITUATION IN REGINA

Doug Archer
Mayor, City of Regina

ABSTRACT

The political realities which govern capital investment in the context of overall provincial priorities for Saskatchewan and possible responses from local government to the issue of financing will be considered. The unique experience of Regina with respect to the recent referendum on property taxes will be discussed.

RÉSUMÉ

Diverses contraintes politiques influent sur l'application des fonds, dans le conteste des priorités d'ensemble de la province. Quelles sont, en conséquence, les solutions qui s'offrent aux administrations locales pour résoudre le probléme du financement des infrastructures? On discutera du cas unique du récent référendum sur les taxes fonciéres à Regina.

INFRASTRUCTURE RENEWAL: THE EDMONTON EXPERIENCE

Mayor Terry Cavanagh
City of Edmonton

ABSTRACT

The City of Edmonton can serve as a model for success in infrastructure rehabilitation. This is due to its early awareness of the problem and the expedient application of funds from the Province of Alberta's AMPLE program. The model suggests that whatever funds all levels of government commit to infrastructure rehabilitation create a net win-win situation where the degree of success varies with the degree of funding.

RÉSUMÉ

La Ville d'Edmonton peut servir d'exemple de réussite en matière de réfection d'infrastructures, puisqu'elle a su diagnostiquer tôt le problème et y affecter opportunément les fonds octroyés en vertu du programme AMPLE de l'Alberta. L'exemple fait ressortir que les fonds, quels qu'ils soient, engagés par tous le paliers de gouvernement à l'égard de la réfection des infrastructures suscitent une situation de gain net où le degré de réussite varie selon l'ampleur du financement.

It is fair to say municipal politicians are the converted where municipal infrastructure problems are concerned. We are reminded every year at budget time, and often during budget reviews as well, of the thousands of kilometres of urban roads and many hundreds of kilometres of sewer and water lines, bridges, sidewalks, and other municipal installations that have reached the point of critical deterioration. The national bill for repair has been estimated to be some $15 billion.

Edmonton is no exception: half our water system, 1,100 km, was built with cast-iron pipe which is corroding. Serious flooding has occurred in parts of Edmonton because of undercapacity of the drainage system. Hundreds of kilometres of sidewalks are broken and we can presently only afford maintenance when serious safety hazards exist. We have 200 bridges in Edmonton whose average age is 25 years. Our goal is to get a life-span of 50 years from our roadways, but funds are only available for major roads, so residential streets are re-paved on a 100-year cycle - nowhere near acceptable.

Overall, approximately $2 billion is needed over the next 10 to 20 years to restore our infrastructure - and yet I believe we are among the more fortunate communities in Canada. Edmonton is recognized as being active in helping to identify solutions to this critical problem. At the same time, we have been relatively fortunate for two reasons:

1. At the local level, we recognized the looming infrastructure crisis fairly early; and for several years now, councils have taken options available to them to address it.

2. Through a fortunate set of circumstances, and a cooperative provincial government, we have been able to assign a significant amount of capital to the problem with a relatively minimal impact on our own source finances.

The awareness and willingness of Edmonton city council to act on the infrastructure issues was developed through the participation of many of us with the Federation of Canadian Municipalities (FCM). Alderman Ron Hayter, myself, and others from Edmonton advised council members regarding the magnitude of what, I feel, is one of the major issues of the next decade.

On its own, Edmonton city council has implemented renewal programs to replace cast-iron water lines, upgrade sewer lines, and relieve older combined stormwater/ sanitary sewers. Progressive measures? Yes, but even so, with city resources, it will take up to 40 more years to replace our old cast-iron watermains. Much too long.

Edmonton's good fortune in being able to commit substantial monies to address the concerns of crumbling roads and failing sewer and water lines is largely owed to our provincial government. When Alberta was mired in a recession, a grant program, the Alberta Municipal Partnership in Local Employment (AMPLE) program, was introduced. By combining provincial grants with targeted capital dollars in our own budget, tremendous inroads have been achieved.

Edmonton's experience on these two points leads me to believe we have some helpful experience to share.

Edmonton's at times severe northern climate makes the cost of infrastructure placement and maintenance expensive. The extremes of temperature (-40°C in winter to +30°C in summer), frost conditions, a degree of isolation, and the area we serve (680 km^2) impose extra expenses, and wear and tear.

Taxpayers in Edmonton know that every spring we need to repair roadways ravaged by winter conditions. The increasing frequency of watermain breaks in winter and flooding and sewer backup during summer rain storms has been well publicized.

We know that the problem is getting worse. Redevelopments near our city centre need greater utility capacity than that required 50 years ago and add to the problem of deterioration. Redevelopment and new suburban development impact downstream sewer service and upstream water service. Road improvements are required by new development as well.

In the 1950s, we repaired about 100 watermain breaks annually in Edmonton; by the early 1980s, the number was up to 1,500 a year. Each break costs $2,500 to $3,000 to repair, so it cost about $3.75 million in our peak year. And there are social costs as well. The inconvenience, distress, and damage to private property are real costs to the community - even if they are not included in the municipal budget. Additionally, new districts established in the 1960s with combined storm and sanitary sewers are overloaded and in desperate need of upgrading.

Residential roadways and sidewalks have traditionally been installed with an expected 100-year life-cycle. Given Edmonton's previously mentioned severe climate, these life expectancy levels are unrealistic; a 40-year life-cycle is more realistic. However, the financing for the more frequent renewal is difficult.

As mentioned, Edmonton has had some success in addressing the problem. To redress an unfair levy on those building new homes in older neighborhoods, city council approved an across-the-board monthly levy on utility bills, amounting to about $2/month/ utility subscriber. The program raises about $4.5 million to finance the upgrading of older combined storm and sanitary sewers.

In 1985, we also began our cast-iron watermain upgrading program. A charge based on a percentage rate of the amount of water used raises an additional $7 million each year.

When possible, we use savings from our snow removal budget to increase our street maintenance program. We have modified our capital priorities to dedicate more money to reconstruction activity rather than new construction. These moves have helped, but the cost of renewal is so massive it is only with provincial and federal help that the whole problem can be tackled.

The provincial government, through its AMPLE program introduced in 1986, committed $500 million to Alberta communities to be allocated over 8 years. It is anticipated that Edmonton's share of the fund will be $125 million over the life of the program. City council has decided to dedicate the bulk of these funds to infrastructure renewal. After just 2 years of operation, Edmonton's AMPLE program has made remarkable progress: three older neighborhoods that are home to about 15,000 people have been refurbished. Eight more of our older districts will be helped by this innovative community-based program over the next 6 years. Input from residents is an important part of AMPLE as is the use of private sector services. I am really positive about this program because it can be seen as a model for what a much larger national infrastructure program can do. Significant employment benefits have been derived from the AMPLE program too, as predicted in the FCM study on cooperative government funding for infrastructure renewal.

The success of our small AMPLE program only makes me more positive about the benefits of a multi-level national strategy. At the same time, it can be discouraging that, even with provincial cooperation, we are only scratching the surface of the growing problems with our roads, bridges, and water and sewer lines.

Experts tell me that some $1.5 billion is needed to fully upgrade Edmonton's infrastructure. With our $1 million in savings on snow removal and $11 million raised with the utility levies, it would take over 100 years to finance the amount needed. Even if we really tightened the screws and bumped input to such a refurbishment program to $50 million annually - a move that would increase property taxes by 20 percent - it would still take 30 years to raise the necessary capital.

Clearly, involvement by the federal level of government is needed. The FCM study demonstrated the cost-effectiveness of infrastructure repairs - that through job creation and capital spending there would be no net impact on the provincial or federal debt caused by a 5-year cost-shared repair program.

By cooperating across territorial boundaries, the three levels of government can solve these problems to the economic and physical benefit of all Canadians. We need to continue to encourage our federal counterparts to consider participating in this win-win plan to help our urban communities now! While it is affordable and before the crisis point is reached.

The Edmonton experience is that voters are becoming more aware of infrastructure problems. A recently approved plan to upgrade sewers in the northeast part of Edmonton is budgeted for $15 million. A proposal to relocate the water intake from one of our water treatment plants would be even more expensive - $97 million. These decisions have Edmontonians' attention. City council will be reminding them - and the federal government - of the burdensome nature of these expenses and of the plan proposed by FCM to approach the problem cooperatively.

We know infrastructure is a difficult concept to explain. There is no simple way to get people excited about the problem; it simply takes hard work. Hard work by municipal governments and FCM as our national organization will make the difference. The provinces have been persuaded to cooperate. All that remains is for our federal counterparts to get on board. We are nearly there, just keep working.

Whether Ottawa will help with the Big Fix program or implement some other mutually agreed-to strategy, federal and provincial assistance is clearly necessary. A national program, with fair allocation of funding to all regions of Canada, is what we are asking.

In conclusion, I would offer Edmonton's application of the province's AMPLE program funds as a model of what can be done, in terms of infrastructure renewal, job creation, and community satisfaction - when a cooperative approach is taken.

EFFICIENCY, INNOVATION, AND PRODUCTIVITY IN PUBLIC INFRASTRUCTURE

With a Case Study in Water Supply and Metering

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ABSTRACT

A complementary relationship between the quantity and quality of capital investment has been discovered. More capital formation has been found to stimulate innovation which, in turn, leads to greater labour productivity and economic growth. This relationship is one we would wish to preserve. For private investment, market forces naturally ensure that greater investment calls forth greater innovation. For public investment, however, market forces are weak, and a deliberate effort must be made by infrastructure managers to take advantage of the opportunities for innovation and efficiency afforded by increased investment.

Although infrastructure systems have matured over the past century, management practices have not matured accordingly. Many public works programs fail to identify and evaluate in consistent terms the proper mix of new construction, expansion, rehabilitation, and operational improvements needed to provide the infrastructure basic to a sound economy - both national and urban. These failures can lead to over-investment in inefficient systems, failure to capture the benefits of technological innovation, inability to achieve the best use of facilities and technology through pricing, and lack of appropriate and timely information for decision-making.

Mirroring the twin concerns of productivity growth through sound capital investment and the need for better public infrastructure management practices, this paper addresses both the general problem and presents a detailed case study.

RÉSUMÉ

On vient de découvrir un rapport complémentaire entre l'ampleur et la qualité des investissements de capitaux. En effet, une formation accrue de capitaux, a-t-on constaté, stimule l'innovation qui, à son tour, donne lieu à un accroissement de productivité de la main-d'oeuvre et améliore la croissance économique. Il s'agit certes d'un rapport que nous voudrions conserver. Sur le plan des investissements privés, les forces du marché font naturellement en sorte que des investissements d'envergure exigent des innovations correspondantes. Pour le secteur public, cependant, les forces du correspondantes. Pour le secteur public, cependant, les forces du marché agissent peu, des sorte que les gestionnaires d'infrastructures marché agissent peu, de sorte que les gestionnaires d'infrastructures doivent délibérément déployer des efforts pour tirer parti des occasions d'innovation et d'efficience que leur procure l'augmentation des investissements.

Les réseaux d'infrastructures ont certes atteint leur maturité depuis un siècle, mais les techniques de gestion n'ont pas progressé en conséquence. Ainsi, de nombreux programmes de travaux publics ne réussissent pas à caractériser et à évaluer de façon cohérente le juste dosage de constructions neuves, d'expansion, de réfection, pas plus que les améliorations opérationnelles nécessaires pour assurer les infrastructures essentielles à une saine économie, tant nationale qu'urbaine. Un tel échec risque d'entraîner des investissements disproportionnés dans des réseaux inefficents, l'impossibilité de récolter les fruits d'innovations technologiques, l'incapacité de faire un usage optimal des installations et de la technologie grâce à la fixation des prix, et le manque de renseignmenets judicieux et opportuns pour prendre des décisions.

Reflétant les deux préoccupations d'accroître la productivité par un investissement judicieux de capitaux et la nécessité de compter sur une meilleure gestion des infrastructures publiques, l'exposé aborde le problème dans son ensemble et livre une étude de cas circonstanciée.

PRODUCTIVITY, ECONOMIC GROWTH, AND THE IMPORTANCE OF CAPITAL INVESTMENT

A nation's economy can produce more goods and services either by employing more factors of production (extensive growth), principally labour and capital, or by increasing the productivity of those factors (intensive growth), i.e., the amount of output per unit of resource input.

Historically, it has been productivity gains that have been crucial to economic growth in North America. Landau (1988) reports work by Solow and others attributing up to 85 percent of past growth to productivity increases, as opposed to increases in the quantity of labour or capital.

Recent Canadian productivity growth has been poor. Labour productivity[1], for example, increased by an average of 4.2 percent/year between 1961 and 1973. Between 1973 and 1984, labour productivity fell to 1.3 percent/year and actually declined from 1981 to 1982.

Capital Investment as a Catalyst of Productivity

What lies behind this collapse in productivity? We may separate this question into labour productivity and capital productivity. It is well known that the productivity of labour, in addition to relying on the quality of labour, depends on the total quantity of capital per worker. The greater the capital intensity per worker, the more leverage the worker has on production.

The importance of capital investment to productivity has been confirmed by work attributed to Dale Jorgenson of Harvard. His work suggests that the productivity of labour is significantly affected by the per-worker rate of capital investment - the amount of money spent in building up the nation's capital stock. Jorgenson has also shown that the growth rate in Japan's productivity has been heavily influenced by the high rate of capital investment in a number of industrial sectors. Landau points out that the rate of Japanese investment was at least twice as high as the rate in many U.S. industries (see Figure l) and our own research indicates similar trends for the Canadian economy.

A "Virtuous" Circle

Less well-documented, but of potentially enormous importance, is the effect of the rate of capital investment on the productivity of capital. Since new capital typically embodies the latest technology, it is clear that the more rapidly new capital is added to the

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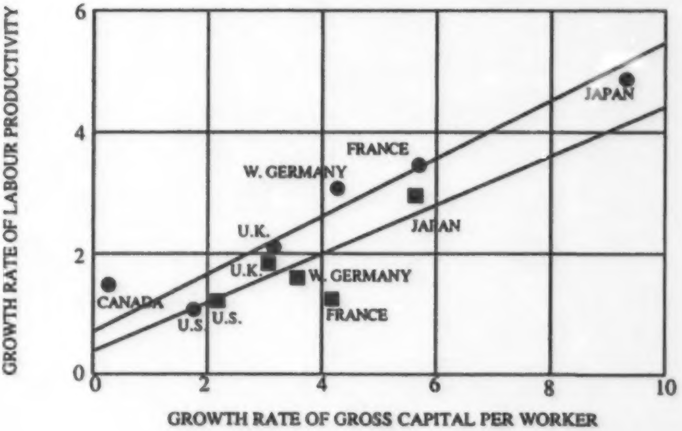
[1] Measured in output per man-hour

FIGURE 1:

INTERNATIONAL COMPARISON OF SAVINGS RATES AND GROWTH RATE OF CAPITAL PER WORKER



Growth rate of capital per worker determines how quickly the productivity of labour rises. Because the U.S. has not increased its investment in capital per worker as fast as Japan has, labour productivity has grown at a lower rate in the U.S. than in Japan over the periods from 1964 through 1984 (■) and from 1979 through 1984 (●). The steeper slope of the line for the data from 1964 through 1984 is a result of the fact that Japan and other counties were then "catching up" to the U.S. by constructing more new plants that incorporated the latest technology.

Source: Authors and Landau, Ralph, "U.S. Economic Growth", Scientific American, June 1988. Canadian data based on calculations made by the authors using data supplied by Statistics Canada.

capital stock, the faster average productivity will grow. The significant point is that the rate of technological progress itself depends on the rate of capital investment. The more quickly new capital is added to the capital stock, the better the quality of that capital will be in terms of embodied technology. This, in turn, means higher productivity and higher growth.

How is it that capital investment stimulates technological advances and productivity growth? According to Landau, the answer is found in the way technological change is incorporated into capital (see Figure 2). He argues that except for a small part devoted to basic science, research and development is seldom undertaken unless its results are expected to be applied in new facilities and superior operating modes that can either increase productivity, reduce costs, or raise the quality of goods and services. Therefore a larger rate of investment creates a market for technological improvements, spurring technological advance.

Landau goes a step further and suggests that faster technological advance, in turn, spurs further investment. This can establish a "virtuous" circle which drives further high rates of growth (see Figure 2). Capital investment leads to research and development to improve technology, which, in turn, creates further incentives for capital investment.

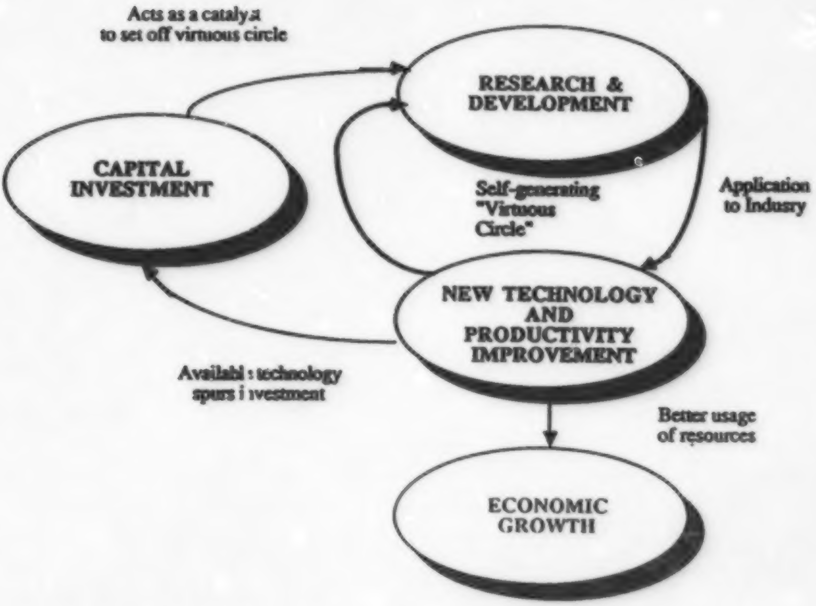
The effect of this proposition is illustrated in Figure 3. Immediate increases in investment can have a longer-run impact on economic growth (Path 4 in the diagram), if the proposition holds true. Otherwise, growth will tend to fall back to its original rate after the initial increase in investment rates.

Statistics on Canadian research and development are consistent with Landau's proposition. As was the case with the rate of capital investment, the rate of Canadian research and development has fallen behind that of our international competitors. Canadian gross expenditures on R&D, after falling during the 1970s, have risen slightly to reach 1.24 percent of GNP in 1984. R&D spending in West Germany and Japan has risen to approximately 2.5 percent of GNP.

Although much of Landau's analysis relates to private investment, there are certain obvious equivalents in the case of public capital formation. Not until 1985, when the federal government authorized $3.5 billion in federal investment in the nation's air traffic control system, did it also authorize Transport Canada to begin in earnest on a program of research and development in advanced automation. This was initiated

FIGURE 2

ECONOMIC GROWTH THROUGH CAPITAL INVESTMENT

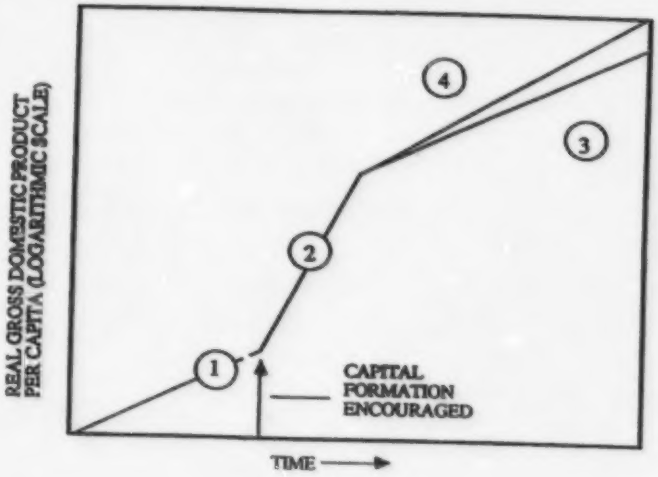

Acts as a catalyst
to set off virtuous circle
RESEARCH & DEVELOPMENT
CAPITAL INVESTMENT
Self-generating "Virtuous Circle"
Application to Industry
NEW TECHNOLOGY AND PRODUCTIVITY IMPROVEMENT
Available technology spurs investment
Better usage of resources
ECONOMIC GROWTH

HOW DOES INVESTMENT IN CAPITAL stimulate productivity to cause economic growth? Research and development is undertaken to effect productivity improvements. The availability of this new technology fuels investment. The investment acts as a catalyst to spur further technological change and set off the self-generating "Virtuous Circle". The result is economic growth through better utilization of resources.

Source: Authors, adapted from Landau, Ralph, "U.S. Economic Growth", Scientific American, June 1988.

FIGURE 3

THE EFFECTS OF CAPITAL FORMATION ON THE ECONOMY



RATE OF ECONOMIC GROWTH is constant (1) as long as capital formation (the construction of infrastructure, new factories and production equipment), labor-force improvements (the training of workers) and technological change (the development of new inventions) take place at a constant rate. When capital formation is encouraged by changes in a nation's economic policy, the growth rate increases (2), since the nation acquires a greater capacity to supply goods and services. If there are no interactions among the rate of capital formation, the quality of the labor force and the pace of technological change, the economy returns to its original rate of growth in the long term (3). But if increasing the rate of capital formation accelerates the rate of labor-force movements and stimulates technological innovation, there may be a longer-term increase in the rate of growth (4).

Source: Landau, Ralph, "U.S. Economic Growth", Scientific American, June 1988.

because air traffic control automation is expected to create disproportionate gains in productivity improvements for the Canadian air administration, for airlines, and for airline passengers in the form of fewer delays and thus more time for productive work.

A similar example is apparent in the case of highway investment where, in anticipation of a large buildup of national highway spending, the provinces, in partnership with the federal government and the Roads and Transportation Association of Canada, have authorized the Canadian Strategic Highway Research Program (C-SHRP). C-SHRP is a 5-year multi-million dollar research and development program looking for more efficient and productive maintenance and construction methods.

From all of this we may conclude that the rate of saving and capital investment is crucial to achieving higher productivity for the Canadian economy generally and for Canadian cities in particular. In addition, it appears that increases in the quantity of capital investment have significant additional benefits; namely, increased quality of capital investment through stimulation of technological advance.

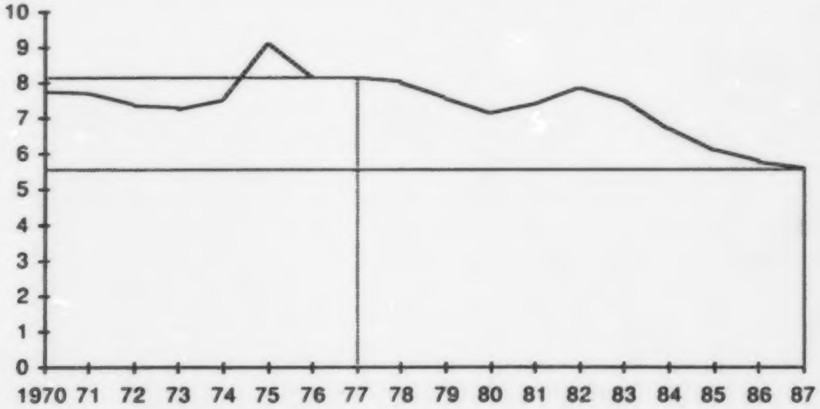
The complementary relationship between quantity and quality of investment is one we would wish to preserve. For private investment, market forces will naturally ensure that greater investment calls forth greater innovation and efficiency. For public investment, market forces are weak, and a deliberate effort must be made by infrastructure managers to explore the opportunities for efficiency, innovation, and productivity afforded by infrastructure investment. This issue is explored in the next section.

PUBLIC WORKS INFRASTRUCTURE, PRODUCTIVITY, AND ECONOMIC PERFORMANCE

Public works are a fundamental and necessary part of the nation's total capital stock. The decline of national rates of investment and productivity growth are reflected in the decline in investment in public works. Figure 4 shows that the percentage of GNP spent on public fixed capital has declined consistently since the early 1970s. If one excludes operations and maintenance and considers capital investments alone, capital expenditures have fallen to half their previous rates: from over 7.0 percent of GNP in the 1960s to 4.1 percent in 1987.

FIGURE 4

PUBLIC SECTOR GROSS FIXED CAPITAL EXPENDITURES AS A PER CENT OF GNP



SOURCE: Statistics Canada, "Private and Public Investment in Canada - Revised Intentions" (61-206), 1988.

The decline in public works investment has, in fact, been more severe than the decline in investment as a whole. The 1970s saw public works capital investment of $36 to $41 for every $100 of private-sector investment. More recent years have seen a ratio of $28 to $36 for every $100 of private-sector investment (Statistics Canada). This declining ratio indicates the eventual possibility that inadequate infrastructure may act as a significant constraint on private-sector productivity growth. Hopefully, the increased awareness of this problem will be translated into sustained corrective action.

Any strategy to boost productivity and achieve higher economic growth for Canada must include a renewed commitment to the maintenance and enhancement of our public works infrastructure. Particularly key is the economic infrastructure, such as water supply and treatment facilities and all modes of transportation, which serve our industries.

To say that more infrastructure investment is necessary, however, is to partly miss the point. We need not only more public works investment, but better investment. As with other forms of capital, the chief hope for increased economic growth comes not from the quantity of capital, but from improved productivity through more efficient and better suited technology.

The achievement of better public investment will require attention and concerted action. In the case of private-sector investment, more investment will lead to better investment. The "virtuous" circle of capital expansion and technological advance will be naturally driven by profit-seeking market forces. In the case of public investment, market forces are weak. Efforts must be made to ensure that innovation in the public sector matches and enhances productivity gains in the private sector.

Better public investment is indeed possible. We should bear in mind that the word 'technology' applies not only to the hard science and the engineering of bridges, airports, and wastewater treatment plants, but also to the means by which we organize ourselves and direct our investments. An airport or harbour built in the wrong place and managed poorly, or a water treatment facility that is larger than economically warranted will not increase productivity. Directing our investment dollars to their most effective points of impact, and ensuring that facilities capture advantages for greater productivity and are efficiently used, will enhance the nation's total productivity and increase the worth of each additional dollar invested.

Our own research and experience leads us to conclude that infrastructure management practices could be substantially improved (Congressional Budget Office, 1986). Many public works programs fail to identify and evaluate in consistent terms the proper timing and scale of new construction, rehabilitation, and operational improvements needed to provide the infrastructure base that a sound economy requires. These failures can lead to over-investment in inefficient systems and an inability to achieve the best, most productive use of facilities through pricing and other administrative factors.

A reversal in these trends would translate directly into stronger national productivity and economic growth.

IMPROVING EFFICIENCY AND PRODUCTIVITY IN PUBLIC INVESTMENT

Three types of improvements can be identified.

- better identification of infrastructure options,
- better evaluation of options, and
- improved use of pricing and other incentives for infrastructure users and managers.

Identification of Options

A key problem here is actually goal identification. Many infrastructure programs have tended to be oriented toward specific physical standards rather than performance goals. For example, during the 1960s and 1970s, there were substantial programs to assist and improve existing urban mass transit systems. These were undertaken during a period when increased reliance on the automobile was making mass transit less important, and when the growing pattern of daily traffic was between suburbs and urban centres. A more effective program of investment might have been directed at roads, or at developing frequent and reliable new transit services between suburbs and urban centres. Had the goals of the program been more functionally defined, such as for "urban mobility", the broader range of possible options could have been identified and evaluated.

Several typical features of programs, among them use of design standards over performance standards, artificially limit consideration of options.

Use of Design Standards over Performance Standards. Because of the apparent ease of administration, programs are often defined in terms of physical standards rather than policy objectives. For example, consider a program to modernize bus fleets rather than improve urban transit; or a program that maintains road condition, regardless of the usefulness or traffic volume on the road. Similar concerns will arise over regulatory programs as well as spending programs. To ensure efficient use of resources, regulations should be sensitive to the possibilities of emerging technology. For example, it is likely that the productivity of airport runways will be enhanced by the availability of microwave landing systems, provided the federal government makes allowance for a reduction in the required separation of planes during poor weather.

Restriction of Attention to Physical Capital Costs. Capacity improvements may come from sources other than the expansion or construction of additional facilities. Improvements in resource management through metering technology, in traffic handling technology, etc. might meet needs more efficiently.

Restriction of Federal and Provincial Assistance to Specific Jurisdictions. If a program offers assistance only to mass transit authorities or wastewater treatment plants, alternative solutions, such as car pool lanes and water metering, may be overlooked.

In general, programs which restrict local choice of method for meeting intended goals best will result in efficiency loss. Improved infrastructure assistance programs would allow municipal authorities the opportunity to define the best means of achieving program goals in their communities.

The theme of defining program goals functionally, and of decentralizing the choice of methods of execution to the management level, is especially important given future trends in industrial organization and remote-monitoring technology. Increased computer capacity and satellite communications are having the long-run impact of decentralizing production. Physical proximity of firm units is becoming less important, while proximity to local markets is increasing in importance. Complementary developments can be seen in the growth of just-in-time inventory control, networked truck dispatching, and remote monitoring of consumption activities. As production moves out of the urban centres to the suburbs and is dispersed to local manufacturing and service sites across the country, infrastructure authorities will have an increasingly better grasp of the infrastructure needs in their areas than that of more central authorities of the infrastructure needs in their areas. The provincial and federal role will be most effective in defining broad program goals and in setting such macro-economic targets as the overall level of investment in public infrastructure.

Evaluation of Options

Once options have been identified, the next logical step is evaluation and comparison. Procedures in this area have historically suffered from several problems, among them use of comparable values, risk and sensitivity analysis, life-cycle costing, etc.

Use of Comparable Values. In order to compare options, a common unit or method of evaluation must be applied to them. All costs and all benefits should be identified. For example, consider the objective of increasing the capacity of a waterway to handle larger ships. Two choices may exist, raising the level of a bridge or dredging a channel. Raising the bridge may seem cheaper until the cost of delaying traffic is considered. In a broader context, comparison of projects between modes also requires common units. Different options should be placed in competition for the same budget dollar.

Risk and Sensitivity Analysis. Major points of vulnerability of programs should be identified and, if possible, programs should be altered or protected to minimize their effect. A positive example of this would be Transport Canada's 1984 proposal to modernize the nation's air traffic control system. The benefits of the program depended in part on the closing and consolidation of some air facilities, and on air traffic projections. Risk analysis (drawn, in fact, from an integrated sister-plan for the United States) discovered that the benefits of this program were not too sensitive to the accuracy of the air traffic forecasts, but were quite sensitive to the ability to close certain air facilities. A 5-year delay of these consolidations would cut the benefits of the program in half. Maintaining the pace of consolidation was thus identified as a key factor in ensuring the success of the plan. In addition, some portions of the program were found to be marginal in their impact. The introduction of microwave landing systems was somewhat premature for the costs involved. Net present values were positive for only some airports and selective implementation of this option was pursued. Note that this is an excellent example of the importance of technological innovation at the management level. The use of advanced evaluation techniques revealed that an apparent advance in science and engineering technology was not a net contribution to productivity for many airports. Just as not all investments are good investments, so not all apparent productivity gains are, in fact, gains to the economy.

Life-Cycle Costing. Capital investment appraisals conducted for individual projects are commonly based on the costs and benefits anticipated for a single year in the middle of the life of a project. This assessment technique disregards the timing of costs and benefits. Projects with large up-front costs and delayed benefits will be less worthwhile than projects with more favourable timing. A preferable alternative would be to assess the cost and benefit profile of a project over its entire life-cycle.

Use of Discount Rates. To evaluate the worth of costs and benefits over different periods, the appropriate discount rate should be used. The use of discount rates gives a higher priority to projects which offer earlier payoffs or postpone costs to later dates. Discount rates should also account for risk. Projects which are riskier for society should offer higher rates of return before they are undertaken.

Incentives for Users

Although user fees should not be used as exclusive criteria for public investment, it must be remembered that user populations usually spring up after the infrastructure investment is undertaken. From time to time, public investment requires a leap of faith in the vitality and future growth of the economy in order to bring that future into reality.

Charging users for the use of services can have several valuable functions, such as more efficient use of the facilities, savings on capacity requirements, etc., which improve the productivity of facilities.

More Efficient Use of Facilities. Fees will help users account for the cost burden they place on the taxpayer and other users. For example, higher landing fees at airports during peak-hour periods will help ensure that the users during the peak are those who place the highest value on that time slot. Air traffic which does not require landing at that particular time will divert itself to cheaper time periods. Thus a scarce resource, runway time, is allocated to those who can make the greatest use of it. Later, we will discuss the role that water pricing can play in fostering more efficient water treatment investments.

Savings on Capacity Requirements. When users are required to pay the costs they impose on infrastructure systems, any increases in capacity required to meet that demand will be known to be justified. Alternatively, if users do not pay the full cost, there will be an increase in demand for capacity stemming from reasons not justified by the cost.

Reductions in Costs. If users are asked to pay the additional costs imposed by their use of facilities, they will take better account of how the manner of their use affects costs. For example, if trucking licenses were tied to the impact of vehicles on road maintenance, this would affect the nature of the trucking technology employed. And if water users pay the costs of water consumption, they are likely to employ more efficient faucet, toilet-flushing, and other related technologies. Moreover, the increased demand for such technologies would stimulate innovation in conservation technologies, reducing their cost and improving their performance.

Demand Signals. Asking users to pay for the cost of their services provides a signal to the provider of the need for the service. If people are unwilling to pay, then the service may not be worthwhile. If an excessive number of people is willing to meet the cost, then more of a facility may be called for.

A CASE STUDY: CAPTURING EFFICIENCY AND TECHNICAL INNOVATION IN WATER SUPPLY

The case of water supply provides a useful and important example of how to identify the most economically efficient and productive scale and timing of capital investment. Key problems facing infrastructure managers are

- how to define and optimize efficiency,
- how to capture the right technology, and
- how to finance worthwhile improvements.

Financial issues are dealt with later. The remainder of this section examines the efficiency question. The section begins with a discussion of the appropriate economic principles and their application to water-metering. We then outline a new computer tool designed to make use of these principles simple and straightforward.

Identifying Productive and Efficient Investments:
The Principles of Benefit-Cost Analysis
In the Assessment of Water-Metering Investments

Although the principles of project appraisal are well known to many infrastructure managers, two areas deserve special attention in the case of water-related investments; namely,

- the identification of benefits and costs, and
- accounting for differences in the time profiles of benefits and costs.

Defining Benefits and Costs. Almost everyone recognizes the term 'benefit-cost analysis' but there is considerable confusion as to what constitutes a real benefit or real cost - that is, a gain or loss in real resources - in contrast to changes that represent transfers from one group in society to another. A higher water rate, for example, transfers dollars from consumers to producers; nothing of value is actually lost overall, and the rate increase cannot be regarded as an economic cost. But the reduction in water consumption that occurs because of the higher rate does represent a real cost to the economy because consumers are led to lose something they value, such as greener lawns or cleaner cars. By the same token, the extra revenue earned by the water authority because of the rate increase is in no sense an economic benefit since nothing of value is gained by the economy overall. But the reduced capital investment requirement that follows from the reduction in water consumption is indeed a real economic benefit since society can put the scarce capital resources to work in more highly valued investments. By finding water-related investments whose economic benefits exceed their economic costs, infrastructure managers can ensure that their investments are truly efficient in the sense that they add to rather than subtract from the value of total economic output.

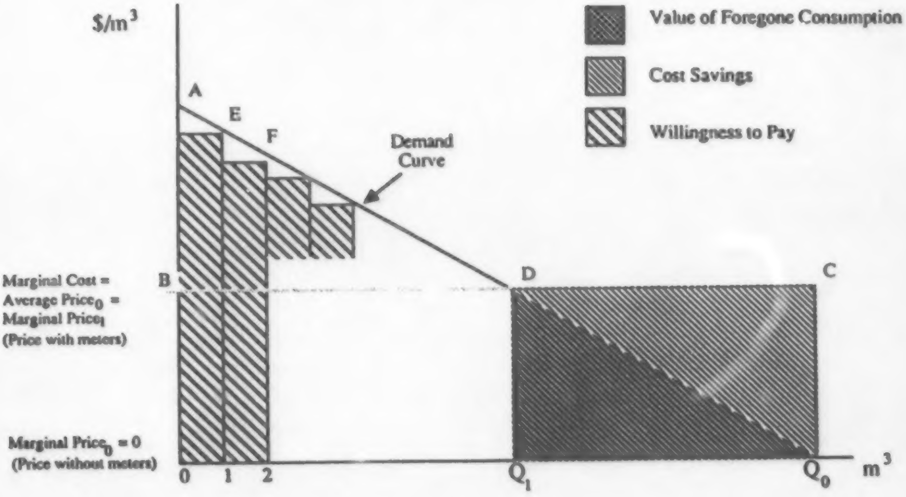
The Benefits of Water Metering. With the introduction of meters, the customer will pay in some proportion to the amount of water consumed, and demand will be tempered accordingly. If demand actually declines with the introduction of metering, benefits will accrue in the form of smaller capital requirements and lower plant operating and maintenance costs.

Figure 5 presents a diagrammatic representation of the economic benefits of metering. Prior to the implementation of water meters, the demand for water is shown as Q_0; and with meters, the demand is reduced to Q_1. The reduction in water demand stems from the ability to charge for water consumption in relation to the volume consumed. Without meters, customers are charged a flat rate for the service and since there is no extra cost for consuming an additional unit of water, the "marginal price" of water is said to equal zero. At the point where the marginal price of service is zero (i.e., $MP_0 = 0$), demand equals Q_0. With the introduction of meters, however, the marginal price of water exceeds zero, since customers must pay extra for the additional units of water they consume.

Even if the per-unit fee charged for metered water service is set equal to the average fee under the flat-rate scheme, demand will decline to the point where the new marginal price of water equals the amount consumers are willing to pay for the last cubic metre demanded (the point where the new marginal price of water intersects the demand curve)[2]. Figure 5 indicates that when a new marginal price (MP_1) of service is set equal to the old average price (AP_0), demand will drop to Q_1.

FIGURE 5

BENEFITS AND COSTS OF WATER METERING



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[2] The average price of water service under a flat-rate pricing scheme is equal to the monthly charge for service divided by the quantity of water consumed. For a customer who consumes 20 m^3 of water per month and is charged $20, the average price of service is $1/$m^3$. If the same customer were to consume 40 m^3 of water per month, the average price would decline to $0.5/$m^3$. Since the additional cost (savings) of consuming more (less) water does not affect the monthly charge, the marginal price under the flat-rate scheme is zero. If, however, a per-unit pricing scheme were implemented where the marginal price of service was set equal to $1/$m^3$, the charge for consuming 40 m^3 per month would increase to $40.

If we understand the change in consumption habits when meters are installed and the cost associated with satisfying different levels of demand, we can estimate the utility's cost savings with meters. The first step is to determine the marginal cost of service, or the additional expense borne by the utility for providing an additional cubic metre of water to consumers[3]. Both marginal capital costs (the expense of adding physical capacity to supply one additional cubic metre of water) and marginal running costs (the expense of paying for labour and materials to supply an additional cubic metre of service) must be included in the estimation of these costs. The total marginal cost of service is shown depicted in Figure 5 as MC (for simplicity MC is assumed to equal the new marginal price of service). Multiplying the change in demand brought about with meters (Q_0-Q_1) times the marginal cost of service provides an estimate of the total cost savings of metering[4]. In Figure 5, these savings are represented by the rectangle Q_1Q_0CD.

Excluded thus far from the discussion of cost savings attributable to metering is the potential reduction in capital and running expenses associated with wastewater collection, treatment, and disposal. Though not included in Figure 5, these benefits should be assessed in exactly the same manner as that outlined above. In cases where savings on the water supply side are minimal, the benefit of water-metering may arise solely from reduced wastewater facility funding requirements.

The Costs of Water Metering. The most obvious costs associated with the introduction of metering are of course the expenses associated with meter purchase and installation. As well, it is necessary to account for the cost of ongoing meter maintenance, and to consider the possibility of higher billing expenses.

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[3] To calculate the marginal costs of service, it is important to include only those costs which vary with changes in demand. Fixed costs which do not change with demand are not relevant for the determination of marginal costs, since providing or not providing one additional cubic metre of water would leave these costs unchanged.

[4] In actual fact, the marginal cost of service may increase with a reduction in the scale of utility operations, resulting in smaller cost savings than otherwise expected. For the sake of simplicity, we have assumed constant economies of scale and fixed marginal costs in Figure 5.

A less obvious economic cost, however, is the value of forgone water consumption under a non-zero marginal pricing scheme. This cost is depicted in Figure 5 by the triangle Q_1Q_0D. Intuitively, this cost may be thought of as the expense borne by consumers for maintaining dirtier cars, browner lawns, and so on, because of their reduced water consumption. To understand the conceptual nature of this cost item, we must introduce what is known in economic jargon as the concept of "willingness to pay".

In economic analysis, the demand curve depicts the relationship between price and the corresponding quantity demanded. From the demand curve shown in Figure 5, consumers are willing to pay a price equal to 0E for the first cubic metre of water, 0F for the second, and so on. Without meters, since consumers demand a quantity of water equal to Q_0 as opposed to any more or any less, this implies that the willingness of consumers to pay for additional service at the point Q_0 is zero (MP_0).

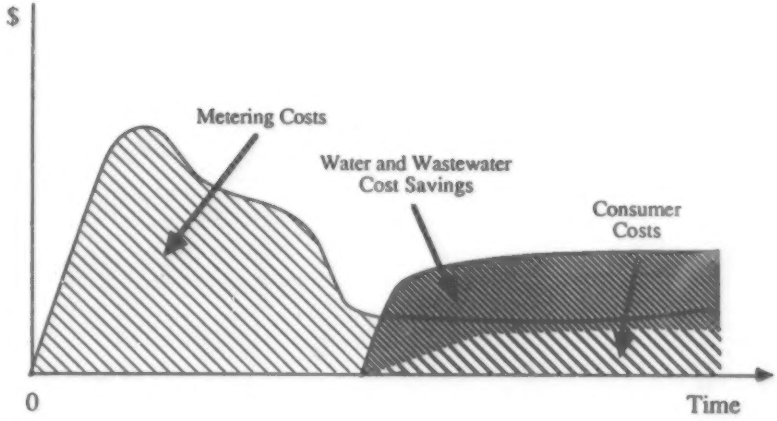
With the introduction of meters, however, demand is reduced to point Q_1. At this level of water consumption, the amount consumers are willing to pay for an additional cubic metre of water is given by 0B (MP_1). According to Turvey (1974), we assume that the average value that consumers assign to water consumption lies midway between MP_0 and MP_1 (Turvey, 1974). The value of forgone water consumption for consumers can be calculated therefore by multiplying the average value of water service times the change in demand due to metering, yielding the triangle Q_1Q_0D.

Accounting for the Time Path of Benefits and Costs: The Net Present Value Test.

Making costs and benefits comparable requires converting the dollar estimates of future effects into equivalent current values (see Figure 6). From today's vantage point, future receipts and payments are worth less than the same amounts due or payable now, not simply because of inflation, but because in current resources they require less than their face value. For example, at a 10-percent interest rate, \$2 seven years into the future is worth only \$1 today, simply because a dollar invested at a 10-percent interest rate will double in value in 7 years. Discounting techniques, which translate future receipts and payments into an amount that, if set aside now at expected long-term interest rates, would cumulate to the future amounts, allow all costs and benefits to be considered in terms of current opportunities. That is, discounted present values reflect not only current opportunities forgone in undertaking to pay future costs but also current resources made available for future benefits.

FIGURE 6:

TIME PROFILE OF METER COST AND BENEFITS



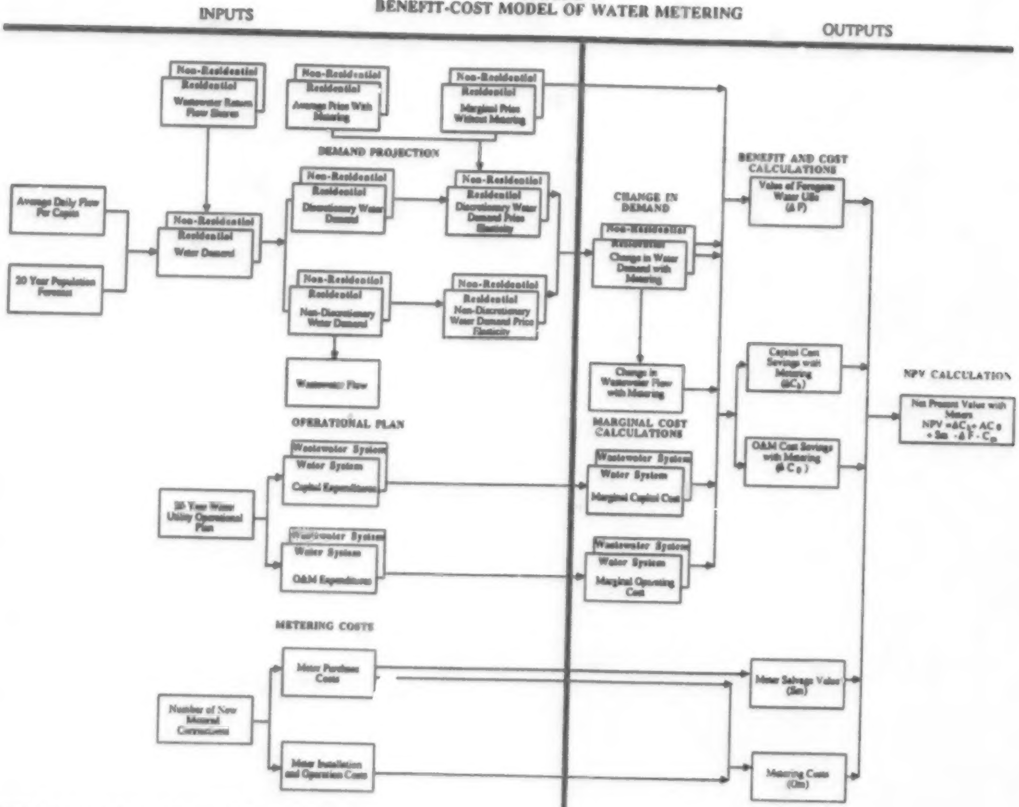
To establish whether investments in metering are worthwhile, it is necessary to subtract the discounted present value of all costs from the discounted present value of all benefits; the result is known as the net present value (NPV) of the investment. A positive NPV means that the investment is efficient. A negative NPV would mean that the costs of metering (including the value consumers place on the benefits they forgo in consuming less water) are not justified by the benefits.

A New Computer Tool for Assessing the Economic Merits of Water-Metering

The benefit-cost principles outlined so far require in their application repetitive and time-consuming computations that can present barriers to the use of economic techniques. To overcome such barriers, the Canadian Water and Wastewater Association (CWWA) is sponsoring the development of a user-friendly, computer-based (Lotus 1-2-3) model designed to make benefit-cost analysis accessible to all municipalities and water authorities.

Figure 7 provides a schematic overview of the CWWA water-metering benefit-cost model. To maximize its use by municipalities the model is flexible by design, thus permitting the analyst to work with available information and specific default parameters. Many of the data inputs to the model are divided according to residential and non-

FIGURE 7
BENEFIT-COST MODEL OF WATER METERING


INPUTS
OUTPUTS
Non-Residential
Residential
Wastewater Return Flow Shares
Non-Residential
Residential
Average Price With Metering
Non-Residential
Residential
Marginal Price Without Metering
DEMAND PROJECTION
Average Daily Flow Per Capita
20 Year Population Forecast
Non-Residential
Residential
Water Demand
Non-Residential
Residential
Discretionary Water Demand
Non-Residential
Residential
Discretionary Water Demand Price Elasticity
Non-Residential
Residential
Non-Discretionary Water Demand
Non-Residential
Residential
Non-Discretionary Water Demand Price Elasticity
Wastewater Flow
OPERATIONAL PLAN
20 Year Water Utility Operational Plan
Wastewater System
Water System
Capital Expenditures
Wastewater System
Water System
O&M Expenditures
METERING COSTS
Number of New Metered Connections
Meter Purchase Costs
Meter Installation and Operation Costs
CHANGE IN DEMAND
Non-Residential
Residential
Change in Water Demand with Metering
Change in Wastewater Flow with Metering
MARGINAL COST CALCULATIONS
Wastewater System
Water System
Marginal Capital Cost
Wastewater System
Water System
Marginal Operating Cost
BENEFIT AND COST CALCULATIONS
Value of Foregone Water Use (ΔF)
Capital Cost Savings with Metering (ΔCk)
O&M Cost Savings with Metering (ΔCo)
Meter Salvage Value (Sm)
Metering Costs (Cm)
NPV CALCULATION
Net Present Value with Meters NPV = ΔCk + ΔCo + Sm - ΔF - Cm

SOURCE: James F. Hickling Management Consultants Ltd., Division of Economics, 1989.

residential customer classes. Greater precision is available to the analyst, however, by working with more detailed groups of customer classes. These classes (not shown) include single-unit and multi-unit residential, commercial, industrial, and institutional customs.

A key component of the model involves estimating the reduction in water demand due to metering. For maximum accuracy, water demand is first divided according to discretionary and non-discretionary water use by class of customer. Measures of price sensitivity, also broken down according to discretionary (e.g., car washing, lawn watering, etc.) and non-discretionary (e.g., water used for washing, cooking, flushing toilettes, etc.) water use, and by class of customer, are then applied in the model to estimate the change in water demand brought about by metering. While users of the model are encouraged to use estimates of water use and price sensitivity based on local conditions, default values are supplied with the model for situations in which information is unavailable.

CWWA Benefit-Cost Model in Detail

For ease of explanation, the CWWA benefit-cost model can be viewed as a number of sub-modules. Each of these sub-modules (depicted in Figure 7 by large bold print) are described briefly below.

Demand Projection. The first sub-module of the CWWA model involves making a 20-year projection of the baseline demand for water and wastewater services[5]. Aggregate demand measures are calculated first, using as inputs a 20-year population forecast for the service area and an estimate of baseline average daily flow per capita. Water consumption is then separated by class of customer based on current utilization patterns, and by discretionary versus non-discretionary applications. Wastewater flow is calculated from model inputs (or default measures) relating to the share of discretionary and non-discretionary water use that constitutes return flow.

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[5] Following standard benefit-cost terminology, the term "baseline" is used in this paper with regard to the status quo case, in particular, prior to the introduction of the evaluation of the metering proposal.

Operational Plan. In order to estimate the cost savings accruing to the utility because of reductions in the demand for water and wastewater services, estimates of future capital and operating costs are required as inputs to the model. These inputs comprise the baseline projections of future expenditures required for the utility to satisfy anticipated demand.

Only those capital outlays and operating and maintenance costs that depend directly on service demand are included. Expenditures that are not affected by demand are not relevant in the case of water-metering, since reductions in water use will leave them unchanged. While a 20-year forecast of capital and operating expenditures is desirable, cost estimates over a shorter time frame may be used.

Metering Investment Costs. Meter purchase and installation costs as well as any additional maintenance and billing costs are an important input to the model. (A catalogue of meter equipment and a review of related operating costs is included with the model users guide to assist with these inputs.) To accommodate cases where only partial metering is proposed (i.e., certain customer classes) and the phasing-in of meters over time, the number of existing connections by class of customer, and the number of planned metered connections for each year during the time frame of the study are required inputs to this sub-module.

Marginal Cost Calculations. To estimate the cost savings which result from metering, annual marginal costs are calculated in the model for both water and wastewater facilities. The method applied to calculate these marginal costs was originally developed by Turvey (1976).

In summary: to estimate the marginal cost in any one year, the first step applied in the model is to calculate the present value of future capital outlays which are intended to satisfy anticipated demand. From this cost, the present value of future capital outlays are subtracted, assuming that the required expenditures are deferred by 1 year because of delayed growth in the system. This difference divided by the change in system demand provides a measure of the per-unit capital cost required to satisfy current demand - the marginal cost of capital. Marginal running costs are then included by simply dividing annual operating and maintenance expenditures by annual demand.

This method of calculating marginal capital costs is well suited to measuring the benefits associated with delaying planned investments in water and wastewater systems.

Since the marginal cost estimates are calculated annually and expressed in terms of dollars per cubic metre of system throughput, they may be applied in conjunction with annual estimates of changes in demand to calculate the cost savings resulting directly from metering.

Change in Demand. The change in demand for water and wastewater services is calculated in the model using two inputs: (1) the change in service prices that accompany the introduction of metering and (2) the sensitivity of customer demand to price changes. Based on existing utility revenues and service demands, the average price of service by class of customer is calculated automatically by the model. The analyst is presented with the option of selecting the current average price as the new marginal price, or testing an alternative marginal price estimate.

Variants of price elasticities are used in the model to calculate the change in water demand from the introduction of meters, i.e., from the introduction of a non-zero marginal price[6]. In the CWWA model, the new demand for water service is estimated with the following equation:

$$Q_1 = (Q_0 * (1 - (MP_1 * e)).$$

In this equation, "e" measures the percentage change in demand resulting from a per-unit increase (i.e., $1) in the marginal price of service (MP_1). For example, with a new marginal price of $0.60 and a value of "e" equal to 0.25, the demand for service with metering would equal 85 percent of baseline demand (1 - (0.6 * 0.25)).

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[6] Price elasticities are the standard measure used in economics to gauge the sensitivity of demand to changes in price. The formula used to represent price elasticities is given by:

$$e = \frac{\%\text{ change in demand}}{\%\text{ change in price}}$$

Since moving from a marginal price of zero to any positive marginal price (i.e., as in the case of metering) is an infinite change, this definition of price sensitivity is limited in its application. To avoid this problem we employ a measure of price sensitivity that represents the percentage change in demand resulting from a per-unit (i.e., $1) change in the price of water and wastewater services.

The price sensitivity of water demand is known to vary according to customer class and water use. Non-discretionary water demand is known to be less sensitive to changes in price than discretionary water demand. Similarly, water use by industrial customers is often thought to be more price-sensitive than water consumed by residential users.

To accommodate these dissimilarities in price sensitivity, the model allows different price sensitivity measures to be specified according to different types of water use and customer class. While default values are provided with the model, the use of alternative measures based on local conditions is encouraged. As well, given the importance of this calculation in estimating the benefits and costs of metering, the model provides the capability to conduct sensitivity analyses. Three cases, using alternative sets of price sensitivity measures, may be tested concurrently with the model to allow a comprehensive assessment of any metering proposal.

Finally, the increment in wastewater flow resulting from metering is estimated for each of the three cases, based on the calculated change in water demand for discretionary and non-discretionary uses and the return flow parameters specified in the demand projection sub-module.

Benefit and Cost Calculations. The benefit and cost calculations performed by the model follow the same principles outlined earlier. Alternative scenarios are generated by the model based on the alternative sets of price sensitivity measures specified in earlier sub-modules.

On the benefit side, cost savings are calculated by multiplying the change in water and wastewater flow by the estimates of capital and running marginal costs[7]. When relevant (i.e., in cases where meters have not reached the end of their economic life by the time the study has finished), meter salvage values are included in the benefit stream as well.[8]

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[7] An alternative approach to calculating the cost savings, which may arise from metering because of reduced demand and potential delays in facility expansion, is to compare projections of capital outlays for both unmetered and metered systems. Needless to say, this approach is very onerous, since it requires the preparation of new investment schedules for each case being considered. The approach applied in the CWWA model avoids this problem by applying estimates of annual marginal costs, calculated by using expenditure data for the unmetered system against estimates of the change in demand brought about by metering. Moreover, the

The costs of meters include the purchase and installation costs of new metered connections as well as the annual expense attributable to meter maintenance and any additional billing requirements. The cost to customers of forgone consumption is also included, calculated by the average marginal price of service before and after metering times the reduction in service demand.

Net Present Value Calculations. Discount rates are selected by the model user, and the model permits the analyst to estimate the NPV of each proposal using various interest rates in order to establish risk and sensitivity.

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method used to measure marginal costs is designed specifically to capture the per-unit capital expenditure associated with meeting anticipated demand requirements in future years. Therefore, the benefits calculated by multiplying baseline marginal costs times the change in demand explicitly captures the cost savings resulting from postponing planned investments.

For utilities that do not face capacity constraints in future years (i.e., utilities that anticipate no future capital outlays to meet rising service demand), the marginal cost of capital is equal to zero, and no capital savings are obtained from further reductions in demand. For utilities that anticipate future investment requirements to satisfy increases in demand, the marginal cost of capital will be positive. In these cases, the capital cost savings attributable to metering will be in direct proportion to the estimated reduction in demand.

[8] To accommodate the possibility of changes in the cost of service due to economies of scale in water and wastewater supply, the model allows the analyst to adjust the "with metering" marginal cost estimate. This capability helps to ensure that the benefits of metering are not overstated in the model and contributes towards a comprehensive evaluation of each metering proposal.

FINANCING INFRASTRUCTURE EXPANSION

A related planning concern is the question of how an increased level of public infrastructure investment should be financed. There are three essential sources of funds: user fees, general tax revenue, and borrowing. Some specific comments are relevant on each of these.

User Fees. User fees are and will continue to be an important source of public funding. It is important, however, not to confuse the efficiency rationale of setting user fees equal to the marginal cost imposed by the user, with obtaining 100 percent financing through user fees. There are many potential reasons why efficient user fees may not add up to 100 percent financing. The classic example is mass transit. People taking the subway are not crowding the streets with their cars during rush hour. Thus it is in the interest of automobile drivers to subsidize mass transit through their taxes to ensure that the roads are less crowded. In general, if it were possible to set user fees that accurately cover total cost, then there would be little reason for government involvement in the first place. The private market could provide the service. Government involvement in infrastructure exists precisely because 100 percent financing through user fees is inefficient.

Tax Revenue. Given that there will be some inevitable portion of infrastructure financing that must be covered through taxes or borrowing, taxation is preferable from a growth perspective. The government's power to tax and then invest the proceeds in the economy is our collective means of forcing a higher savings rate in the economy and to achieve our common goal of higher growth.

Borrowing. If there is a constraint on tax revenue, then borrowing will be necessary to finance infrastructure investment. By definition, borrowing increases the deficit. The concern raised in this paper is that the high deficit has raised interest rates and reduced private investment in the economy. However, a distinction must be made between deficit borrowing which is used to finance tax cuts - implicitly increasing consumption - and borrowing which itself is used to finance public investment in the economy. If public investments are undertaken wisely, the latter form of deficit pays for itself by generating future income for the nation. The decision is then one of a relative preference between public and private investment as a source of growth. Since both are necessary, the concern over the size of the structural deficit should not be used to inhibit or prevent the necessary expansion of public infrastructure investment.

A final comment related to efficiency in public investment and financing involves the relationship that exists between revenue requirements and the scale of public infrastructure. Simply, while over-supply of infrastructure is inefficient on its own, the economic drawbacks may be exaggerated by the financial burden imposed on society. With regard to the case of water supply outlined above, it is clear that, when deemed efficient through benefit-cost analysis, meters provide an opportunity to reduce capital requirements and ease revenue requirements (i.e., service fees or intergovernmental transfers, or both). Concerns about financing of public infrastructure expansion can often be addressed by seeking out efficient, but less obvious, investment options.

CONCLUSION

There is a need for a national commitment to economic growth. If Canada is to experience an increasing standard of living and preserve its world leadership role, higher growth rates than those currently forecast must be achieved.

Higher growth rates require increased rates of capital investment, both private and public. Increased investment will promote productivity by increasing the productivity of labour and by accelerating the rate of technological advance.

Infrastructure investment must play a key and necessary role in any plan to achieve higher productivity and growth. Increased productivity in the private sector can be matched by technological innovation in public-sector investment. Technology must be perceived to include the way in which investments are identified and undertaken. There exists much room for improvement in the identification of investment options, their assessment, and the regulation of their use. These include:

- the comprehensive assessment of alternative modal options to meet given transport needs;
- the use of practical cost measures that account for life-cycle costs and the timing of benefits; and
- the use of user charges to ensure more efficient use of existing facilities and to guide the establishment of additional facilities

These innovations, combined with an overall commitment to higher investment levels, will bring Canada greater economic growth, productivity, and international competitiveness.

ACKNOWLEDGMENT

The authors are indebted to Peter Lok for his excellent suggestions and assistance in the preparation of this paper. We are also very grateful to Kim Grant who provided word-processing and graphics support through a series of many drafts.

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OUR NEXT CHALLENGE: ELIMINATION OF SEWAGE OVERFLOWS

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ABSTRACT

The Ministry of the Environment for Ontario, in co-operation with the Municipal Engineers Association and other groups dealing with pollution, established a committee in the late 1970s to study stormwater management. Many of the findings of this committee were included in the Ontario Ministry of the Environment's publication "Water Management: Goals, Policies, Objectives and Implementation Procedures" issued in November 1978. This book established a program for water quality objectives. This led to the Municipal Industrial Strategy for Abatement (MISA) program in Ontario to encourage industries to clean up their water effluents. This led further to more stringent requirements for municipal sewage treatment plants and a need for treatment or elimination of combined and sanitary sewer overflows. In order to deal with overflows, they must be located and contributors identified.

RÉSUMÉ

Vers la fin des années 1970, le ministère de l'Environnement de l'Ontario mettait sur pied, en collaboration avec l'association municipale des ingénieurs et d'autres groupes intéressés aux effets de la pollution, un comité chargé d'étudier la gestion des eaux pluviales. De nombreuses conclusions émanant du comité sont reprises dans le document intitulé "Water Management: Goals, Policies, Objectives and Implementation Procedures" que publiait le ministère de l'Environnement en novembre 1978. Le document fixait des objectifs en matière de qualité de l'eau. C'est ainsi que l'Ontario s'est dotée de la Stratégie municipale et industrielle de dépollution (SMID) dans le but d'inciter les industries à des exigences plus rigoureuses les usines municipales d'épuration des eaux usées et reconnu la nécessité de traiter ou d'éliminer les déversements des égouts unitaires et séparatifs. Mais avant de "traiter" la question des déversements, il faut tout d'abord repérer les endroits où ils se produisent et cerner les facteurs en cause.

INTRODUCTION

We hear much about the Municipal Industrial Strategy for Abatement (MISA) program which will be implemented in Ontario in 1989. This is the most recent regulation of many instituted by the provincial government in an effort to clean up the environment and make it pollution-free.

Concerns at the local level are not about the effectiveness of the Bill but about its costs. Expressions of concern have come from municipal councils, such organizations as the Association of Municipalities of Ontario, and industries. And there is no question, this will be costly to both industries and municipal governments. The costs of monitoring and testing effluent from all industries alone will be considerable. But, equally costly is the requirement for the elimination of sanitary and combined-sewer overflows - an identified and worrisome cause of pollution. Scarcely a word of opposition has been heard with respect to this requirement. The concern in Niagara is how much of these costs the local property owners will bear.

The history of provincial and federal subsidies for similar programs does not compare favourably with experiences in other countries - the closest being the United States. Municipal councils and individuals fear that more and more costs will be channelled from senior governments to the final port of call, the pockets of the land owners.

HISTORY OF NIAGARA

The Regional Municipality of Niagara came into being on January 1, 1970, as a result of legislation passed by the Province of Ontario. This legislation combined 26 municipalities and two counties, Welland and Lincoln, to form the Regional Municipality of Niagara and 12 lower-tier municipalities. Arterial roads, trunk water mains, supply of potable water, trunk sanitary sewer mains, and treatment of sanitary sewage became the responsibility of the Region of Niagara. The responsibility for local road systems, local watermains, and local sanitary sewer mains was assigned to the member municipalities.

In 1970, sewage was treated at primary treatment plants and a number of lagoons, most of which were deficient in capacity and level of treatment. Several municipalities were still constructing combined sewers, a practice which the Region immediately prohibited. Four pollution control plants, which were constructed in the late 1960s, soon proved to be undersized.

The first step of the Public Works and Utilities Committee was to formally assume the sewer and water system. The consulting firm of James F. MacLaren Limited was engaged by the Province of Ontario to inventory existing facilities and recommend a regional system. MacLaren's report was received and accepted in December of 1969, and a bylaw was prepared establishing the regional system.

THE SEWAGE SYSTEM

Our next step was to establish a plan to improve sewage treatment and to build plants to provide a minimum of primary treatment for sewage where needed. Shortly thereafter an order was received from the Ministry of the Environment to reduce the discharge of phosphorus in sewage effluent to 1 mg/L.

In 1970, algae was choking natural growth in the Great Lakes, especially Lake Erie. Studies by federal and provincial governments indicated this was due to eutrophication of the lakes. Canada and United States agreed to reduce the amount of phosphorus entering natural waters leading to the Great Lakes system. Provincial studies indicated that much of this eutrophication was coming through sewage treatment plants, and reduction of phosphorus output could be achieved fairly simply at a minimal construction cost at sewage treatment plants, but with an ongoing chemical and maintenance cost. To meet the requirements of the Ministry of the Environment, Niagara immediately engaged consultants to undertake jar- and pilot-scale testing at all sewage treatment plants to determine the best means of reducing phosphorus output. By the end of 1975, we had reached the objective mandated by the province.

PARC NIAGARA REPORT

To establish a capital budget to attempt to resolve the problem of sewage treatment, we met with all consultants who had undertaken previous studies in Niagara. We discovered that most of the work previous to 1970 was undertaken by two consultants, Proctor & Redfern Group and R. V. Anderson & Associates Ltd. We requested that these two consultants form a consortium, which they named the PARC Niagara Group, to review all significant engineering reports and interview all consultants who undertook work in Niagara. From this, the consortium was requested to prepare a plan to improve sewage facilities in Niagara, to recommend priorities, and to recommend a 5- and 10-year capital budget.

The PARC Niagara report was accepted by council and Niagara entered into an agreement with the Ministry of the Environment for special financing to carry out the first 5 years of the program. As a result, by the late 1970s, we were able to provide complete primary treatment at all our plants, including the elimination of some lagoons and improvements to the remaining ones. By the early 1980s, we had reduced our treatment plants to eight, and our lagoons to four.

SECONDARY TREATMENT

At this point, we are continuing our program for adding secondary treatment to two remaining primary plants in Fort Erie. The construction at the Anger Avenue plant is underway and it should be operational in November 1989. At the Crystal Beach plant, we are in the middle of a class environmental assessment process, and hopefully, construction will be underway by early 1990.

In addition, we are also upgrading three major water pollution control plants in our region, both hydraulically and biologically. This is to ensure that our plant effluent quality will meet the current non-compliance criteria of 25/25/1 mg/L for BOD, suspended solids, and total phosphorus respectively, based on the average of the analysis from any four consecutively weekly composite samples of final effluent, flow weighted. This multi-million dollar program includes the following plants:

(a) Nitrification and upgrading of Welland water pollution control plant from 9 MIG/d to 12 MIG/d. (Construction is underway and the upgraded plant should be operational in November 1989. Total project cost is $15 million.)

(b) Upgrading of Port Weller water pollution control plant in St. Catharines from 8.25 MIG/d to 12.375 MIG/d. (Construction is underway and upgraded plant should be operational in May 1989. Total project cost is $8 million.)

(c) Upgrading of Port Dalhousie water pollution control plant in St. Catharines to its rated capacity of 13.5 MIG/d. (This is a 3-year $10 million program with Phase I construction to commence in April 1989.)

The staff realized early, and our operations experience confirmed, that the guidelines set by the Ministry of the Environment and used by consultants in designing biological process, were inadequate in several areas. To overcome this problem, we engaged process consultants for design recommendations to treat sewage in the most economical way and still meet increasing requirements of Certificates of Approval of the Ministry of the Environment. Civil engineering consultants were hired only after we reviewed and adopted the process consultants' report. We found that this not only eliminated past problems because we were actually able to design for specific and often unique requirements, but in several cases, it also reduced our capital costs substantially.

Water reaching our pollution control plants must be treated, and most Certificates of Approval issued by the Ministry of the Environment today require that we do not exceed a discharge of 25 mg/L BOD, 25 mg/L SS and 1 mg/L phosphorus based on a 4-week average. To consistently achieve this result, we undertook considerable statistical analysis which has shown that we must operate our plant at or below normal effluent discharge of 10/10 and 1/2. Statistically, we know we shall have failures and this type of requirement certainly adds to our treatment costs - another burden to the taxpayer.

At our Welland pollution control plant, because of low flow in the receiving stream, the Welland River, we were required to provide tertiary treatment in the form of sand and anthracite filtration. This added about $5 million to the capital cost of the plant and certainly increased the annual operating cost.

Design Flows

One of the most difficult problems in designing a sewage treatment plant is attempting to determine the flow that should be treated. It is fairly easy to establish normal dry-weather flow and to determine its fluctuations. It is extremely difficult to determine what extraneous flows enter the system by infiltration from weeping tiles, rainwater leaders, leaking sewers, leaking laterals, leaking manholes, catchbasins, etc. In the past, the Ministry of the Environment normally required that we design for two times the dry-weather flow; and from a design viewpoint, this is fairly easy. Beyond two times the dry-weather flow, insufficient nutrient remains in the sewage to maintain the bacterial colony at the plant. We soon discovered that the plants designed to handle two times the dry-weather flow experienced overflows during rainstorms not only at the plant but also throughout the system. This is undesirable.

Our process studies generally indicated that anything beyond twice the dry-weather flow produced a sewage too weak to provide effective treatment in a biological system and created the danger of washing the system out. Therefore, at our Fort Erie Anger Avenue plant, we designed two trains of treatment, one to handle up to twice the normal-weather flow for biological treatment and one to handle excessive storm flows (that beyond twice the normal-weather flow) for primary treatment and disinfection.

In the case of the Welland plant, we were requested to deal with the ammonia remaining in the plant effluent due to the nature of the receiving stream, the Welland River. Because of stringent ammonia criteria, our consultant has recommended two streams of flow for treatment, each having a capacity of 12 MIG/d to make up a peak flow of 24 MIG/d. One stream receives full biological treatment, while the extraneous flow is provided with chemical sedimentation and primary clarification. The effluents from these two streams are then blended to be filtered prior to disinfection. This is to ensure that the plant effluent will be statistically within the compliance limits set by the Ministry of the Environment. The filtration process increased our project cost by almost $5 million.

MUNICIPAL INDUSTRIAL STRATEGY FOR ABATEMENT (MISA)

In 1989, it is anticipated that municipalities and industries in Ontario will adopt the MISA program. This will require much closer monitoring of discharges to the municipal sewer system, therefore necessitating much closer cooperation with industry. Until now, we have monitored effluents from 170 industries for five or six parameters. Under the MISA program, we are required to monitor effluents from 1,000 industries for 150 to 300 parameters. This will require an increase in staff, additional laboratory time to carry out necessary testing, and staff time to meet with representatives from industries to discuss resolution of problems. In our opinion, the major problems with the MISA program are co-ordination of resources, finances, and acquisition of personnel to carry out the program.

ST. CATHARINES POLLUTION CONTROL PLANNING PROGRAM

The first attempt to measure overflows in Niagara was undertaken by the Ministry of the Environment. For many years, most beaches near the City of St. Catharines have been closed in the summer because of contamination by fecal coliforms. The source of these bacteria has not been fully identified.

The Ministry formed a committee consisting of representatives from the Ministry, City of St. Catharines, City of Thorold, and Region of Niagara to engage services of a consultant to attempt to identify the problem of overflows. It was fairly easy to identify sanitary sewer and combined-sewer overflows, and discharges to the natural waters from industry. It was not as easy to identify where these waters came from. Massive sampling programs were undertaken and results used to calibrate three models to predict future conditions as changes are made. These include discharge models, transport models, and lake models. The St. Catharines study has been underway for 3 years and a report is expected in the summer of 1990. It is hoped that this report will both give guidance to the City of St. Catharines regarding the reduction of extraneous waters entering the sewers and indicate where retention facilities should be built. The study is incorporating environmental assessment requirements as part of the selection of alternatives. Hopefully, the report will also give some idea what flows have to be dealt with at the pollution control plant. At that point we can complete our design to provide a facility to handle these overflows and provide adequate treatment.

FORT ERIE POLLUTION CONTROL PLANNING PROGRAM

In 1987, as a result of attempting to design a secondary pollution control plant for the Town of Fort Erie, we entered into an agreement with the Ministry of the Environment to undertake what became known as a pollution control planning and infrastructure rehabilitation program for the Town of Fort Erie. We established a committee with the Ministry of the Environment, Region of Niagara, and the town. Niagara took the lead in engaging staff to carry out this particular program. A series of measuring devices were set up in manholes along the system to obtain dry- and wet-weather flows. It was found that most rainfall events are extremely variable in relation to location, and rainfall meters should be located within a catchment area.

A statistical approach was tested for reliability and then used to evaluate the data obtained from flow meters. This approach is expected to lead to conclusions much faster than conventional modelling techniques, although such models may be used to test anticipated results of various control alternatives. Our work includes establishing the Sewer Inventory Management System (SIMS) as a demonstration project for the tri-committee.

NIAGARA-ON-THE-LAKE STUDY

The Town of Niagara-on-the-Lake prepared a multi-year program for rehabilitating its sewers, but in order to be eligible for provincial assistance, the Ministry of the Environment required this be confirmed by an infrastructure rehabilitation study. Also, the Ministry of the Environment required that the Region either pump all sewage reaching the main pumping station or correct excessive inflow/infiltration problems. These problems and a development freeze, resulting from the lack of adequate treatment capacity, led us to initiate an infrastructure rehabilitation study in Niagara-on-the-Lake immediately. The work included establishing SIMS, flow-monitoring, and recommending solutions. A draft report was received in January. Its conclusions will be verified by additional flow-monitoring during the spring runoff period. A final report will be ready in June.

FEASIBILITY STUDY

Appreciating that the same problem existed in seven other municipalities, the Region of Niagara engaged the firm of R. V. Anderson & Associates Limited to carry out a feasibility study for the Niagara pollution control plan in 1987. We received their report early in 1988. This report found that each municipality was unique and thus required a slightly different approach. It also clearly indicated that, in addition to a pollution control plan program for identifying overflows, it was also necessary to do an infrastructure rehabilitation study to locate and determine the need for repairing or replacing underground sewer systems and laterals to houses.

As a result, we established study areas to cover the region - Lincoln/Grimsby/ West Lincoln, 1989; City of Port Colborne, 1989; City of Welland/Town of Pelham, 1990; and City of Niagara Falls, 1990.

These studies indicate that building pollution control plants to handle whatever flows might reach them results in very high capital and operating costs. These costs may be reduced by constructing holding facilities to retain overflows until storms have passed. Costs can be further reduced through elimination of combined sewers (a very expensive program) and by repair or replacement of sanitary sewers and manholes to eliminate extraneous flows. Another significant source of infiltration is along pipe connections (laterals) leading from sanitary sewers to houses. They must be repaired or replaced as well.

RAINWATER LATERALS AND WEEPING TILES

Two other major contributors of stormwater to sanitary systems are rainwater leaders and weeping tiles. Most municipalities now prohibit connections of rainwater downspouts to sanitary sewers yet allow them to flow onto the ground adjacent to the house. If water is not carried at least 3 m away from the house, as required by most bylaws, or if grading is such that the water flows back to the house, water will flow or seep along the basement wall to the weeping tile and into the sanitary sewer. If all rainwater leaders and weeping tiles around foundations could be discharged on the surface of the ground where water would enter either natural watercourses or the water table, a lot of our problems from extraneous flows would be eliminated.

In newer subdivisions, it is possible to demand that weeping tiles or rainwater leaders not discharge to the sanitary sewer system, thereby prohibiting this source of inflow to the sanitary sewers. This will be a requirement in the Region of Niagara. Problems in older built-up areas are not so easy to resolve.

An interesting proposal was developed by the City of London whereby it provides a grant of $1,000 to $1,200 to the taxpayer for the removal of weeping tiles from sanitary sewer systems. This usually requires the installation of a sump pump to eliminate the need for discharging the water to the ground. People have the concept that water just disappears into sanitary sewers, and most are not interested in having a sump pump with all the related problems. These people had to be educated to the potential for cost-saving resulting from in-house control of extraneous water. This was difficult but proved possible and cost-effective.

It is equally hard to convince people to regrade their property where fill designed to protect the house has settled resulting in flow toward, rather than away from, the dwelling. Rainwater must be carried to a point where it will not flow back to the foundation and into weeping tiles or through basement cracks.

CONSERVATION OF WATER

In Niagara, we prepared a position paper on conservation of water both from a viewpoint of usage and also its discharge to the sanitary sewer system. We hope this is a means of presenting a message to the public that a problem does exist, that it can be resolved, and that we will all stand to save money. The public will pay lower sewer and water rates, the municipality will invest less capital for plant construction, and will receive sewage which can be more readily treated biologically than weaker waters.

If the MISA program is adopted, our overall system budget is anticipated to increase considerably as additional staff are hired to monitor industry to ensure its compliance with new discharge criteria. Laboratory costs, as stated earlier, are also expected to rise significantly. At this time, we are unable to even guess at the impact of stormwater treatment in the future - and more appropriately, combined-sewer overflow treatment now - will have on our overall costs. We fear that it will be considerable.

It is easy to make general statements about the elimination of overflows but to actually achieve results is a different matter. It requires a great deal of expensive work to identify the overflows: first, by monitoring flows in an area; second, by TV inspection of sewers to determine their condition; and third, by smoke-testing sewers to locate illegal connections to the sewer system. Once these overflows have been found, we must take steps to require owners to correct them.

Costs

We estimate that our infrastructure rehabilitation studies about pollution control planning will cost about $6 million, of which 50 percent is a subsidy from the provincial Ministry of the Environment. We do not yet have any idea about the cost of the plant improvements required, the cost of retention facilities, or the funding required to replace or repair the infrastructure and laterals in order to block off undesirable extraneous waters. It certainly will be well in excess of $100 million, a burden we hesitate to put on our ratepayers.

The Niagara-on-the-Lake rehabilitation program, based on the local sanitary sewer system which the first phase of the infrastructure study indicated was appropriate, entails an estimated annual cost of $230,000 to service a population of 3,500. If a similar rehabilitation cost is applied to our serviced population, additional annual rehabilitation costs in the order of $20 million annually might be required by municipalities in the area. This is likely to be an ongoing expense.

As an indication of our increasing cost for sewage treatment, our overall budgets were as follows:

Year	Costs for Sewage Treatment
1972	$ 2,850,594
1975	5,259,305
1980	9,522,923
1985	17,152,076
1989	22,000,000+ (projected)

To take one sewage treatment plant as an example: In 1970, we budgeted $234,210 for the operation of a 10-MIG/d primary plant that we assumed upon inception. Wages accounted for 48.3 percent of the overall budget, chemical costs were 2.6 percent, and sludge disposal accounted for 7.7 percent.

By 1978, wages had nearly doubled, without an increase in staffing level, whereas chemical costs had risen 30 times, reflecting the cost of phosphorus removal by the addition of ferric chloride. Our sludge disposal costs increased only marginally and represented only 4.1 percent of our total budget, a decrease. This is due to the on-site lagooning practice at the plant and would not be mirrored across the board. Wages still only represented 41.1 percent of the total budget of $547,000, while chemicals came in at 33.6 percent.

In 1989, we have budgeted $1,573,789 for the operation and maintenance of this same plant. Secondary treatment was added in 1985 and staffing levels were consequently increased from 14 to 16 persons. Wages today are nearly thrice those of 1978, but still reflect only 42.4 percent of the budget. The cost for chemicals has increased by only a further 20 percent, whereas sludge disposal costs have increased nearly six times over the same time period, reflecting an increase in sludge production with secondary treatment, yet these still only represent 8.9 percent of the total budget. Energy costs, to run secondary works, have increased substantially over primary-only treatment.

In future years, we expect our operating costs to increase somewhat faster than inflation, reflecting the increased costs of maintaining tighter control over the plant operation to ensure compliance with stricter effluent quality regulations. We also assume that land application of digested sludges will continue to be an acceptable method of disposal.

Our 5-year capital and maintenance projection provides for an annual 7 percent increase. Our increase, based on works which have been identified, is 9.45 percent annually for the next 5 years. These projections do not take into consideration the MISA Program but allow expenditures to provide capital works to handle overflow problems.

The Ministry of the Environment provides a subsidy for capital projects varying from 15 to 33-1/3 percent. There is an upset limit on funding available and many projects undertaken in excess of that funding are at 100 percent regional cost. In the past, we received CMHC (federal) funding; but since 1985, have received no federal funding whatsoever. This is in sharp contrast to the United States where substantial federal and state funding is available to local municipalities to carry out works to improve the environment and to construct roads, bridges, and other municipal projects. (See Table 1 for construction costs of primary expansion and secondary addition.)

CONCLUSION

We cannot and do not argue with the premise that we must clean up our natural waters, particularly since we require clean water for residential, commercial, industrial, recreational, and other uses. We attempted to meet this objective by providing secondary treatment at all our plants, thereby removing 90 to 94 percent of all contaminants. In Welland, where we provide tertiary treatment, we remove 96 to 98 percent.

We are concerned about the MISA program and its added costs, but appreciate its need. The sewage overflow program, which is our next challenge, brings home the high cost of tidying up our sewer systems, and collecting and treating sewage overflows. In the past, these were discharged and forgotten. With today's methods, it is possible, at a cost, to repair or line sewers with plastic liners to eliminate infiltration. In many cases, however, sewers must be replaced particularly where combined sewers exist or where sewers are very old and rehabilitation is impossible.

Costs in the past have been borne by the local taxpayer. In recent years, some subsidy has been received from the Province, particularly for sewer rehabilitation. It would seem to us that the federal government should also accept some responsibility to assist in the renewal of infrastructure which would lead to a reduction in capital costs for plant construction and operation.

Table 1

Construction Costs

Project	Costs ($ x 10^6)
Primary Expansion	
Niagara Falls WPCP (1977)	$ 2.2
Anger Avenue WPCP (1977)	$ 2.6
Secondary Addition	
Welland WPCP (1973 and 1981)	$ 4.3
Baker Road WPCP, Grimsby (1976)	$ 9.0 *
Port Dalhousie WPCP, St. Catharines (1972 and 1975)	$ 5.5
Seaway WPCP, Port Colborne (1978)	$ 5.9 *
Niagara Falls WPCP (1984)	$12.0
Anger Avenue WPCP (1988)	$13.5 **
Welland WPCP Nitrification (1988)	$15.0 **
Port Weller WPCP Upgrading St. Catharines (1988)	$ 8.0 **

* costs included primary treatment

** costs are estimated project costs

ACKNOWLEDGMENTS

I sincerely thank members of the Public Works Department of the Regional Municipality of Niagara who assisted in preparation of this paper, in particular, E. R. Simonen, P.Eng., Head of our Environmental Services Division; Kenneth Yu, P.Eng., Head of our Engineering Services Division; and M. L. Lywood, P. Eng., Assistant Division Head, Water and Pollution Control Division. I especially thank my wife, Nancy, for her encouragement and editing.

REGIONAL WASTEWATER MANAGEMENT CONCEPT

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ABSTRACT

The regionalization of some wastewater utility systems in Alberta resulted from overloaded facilities, rapid growth in suburban communities and stricter environmental standards. This paper discusses the rationale for regionalizing wastewater facilities and reviews the implementation process. It also examines various financial, administrative, and technical concerns from the municipal perspective. Finally, the current operation of the regional system is assessed and future issues are discussed.

RÉSUMÉ

En Alberta, la régionalisation de certains réseaux d'épuration des eaux usées tient à la surcharge des installations, à la croissance rapide des banlieues et à l'adoption de normes de protection de l'environnement plus rigoureuses. L'exposé se penche sur les motifs poussant à régionaliser les installations d'épuration des eaux usées et passe en revue le processus de mise en oeuvre. Il s'attarde également à étudier les préoccupations financières, administratives et techniques qui attendent les municipalités, en plus d'évaluer le fonctionnement actuel du réseau régional et d'aborder les questions de demain.

INTRODUCTION

The Capital Region Sewage Commission provides sewage transmission and treatment services to 12 municipalities surrounding the City of Edmonton (see Figure 1). However, the City itself is not a member. The member municipalities comprise four cities, four towns, and four counties with a total service population of about 130,000. The transmission system, when completed later in 1989, will consist of 120 km of gravity sewer from 600 to 1370 mm in diameter, five pumping stations, and 53 km of forcemain. The system was sized to accommodate growth for at least 20 years. Sewage is treated at a mechanical secondary treatment plant with a 90-ML/d average flow capacity. The plant is designed to be expanded up to four times its initial capacity. Total capital investment in the plant and transmission system will be $148 million.

REGIONAL UTILITIES

The establishment of the multi-municipal or regional concept is not new to most regions of Canada. What may be unique is the way the regional concept developed in Alberta.

Financial Assistance Programs

In the early 1970s, the provincial government established the municipal sewage treatment grant program. Shortly afterwards, the federal government established the agriculture municipal services program for the provision of water supply. Thirteen Alberta municipalities or agriculture service centres were identified as being eligible for funding under this program. The Province followed with the establishment of a municipal water supply program that applied to all other municipalities in the Province and which paralleled the federal program.

These programs, administered by Alberta Environment, were to provide financial assistance for the establishment of adequate water supply or sewage treatment facilities. The programs covered treatment and major trunk or transmission lines. Eligibility also applied to the entire distribution or collection facilities in communities where there was no existing system.

When these programs were established, most of the industrial development was located in the larger centres, which had existing water and sewage services. At the same

Capital Region Sewage System

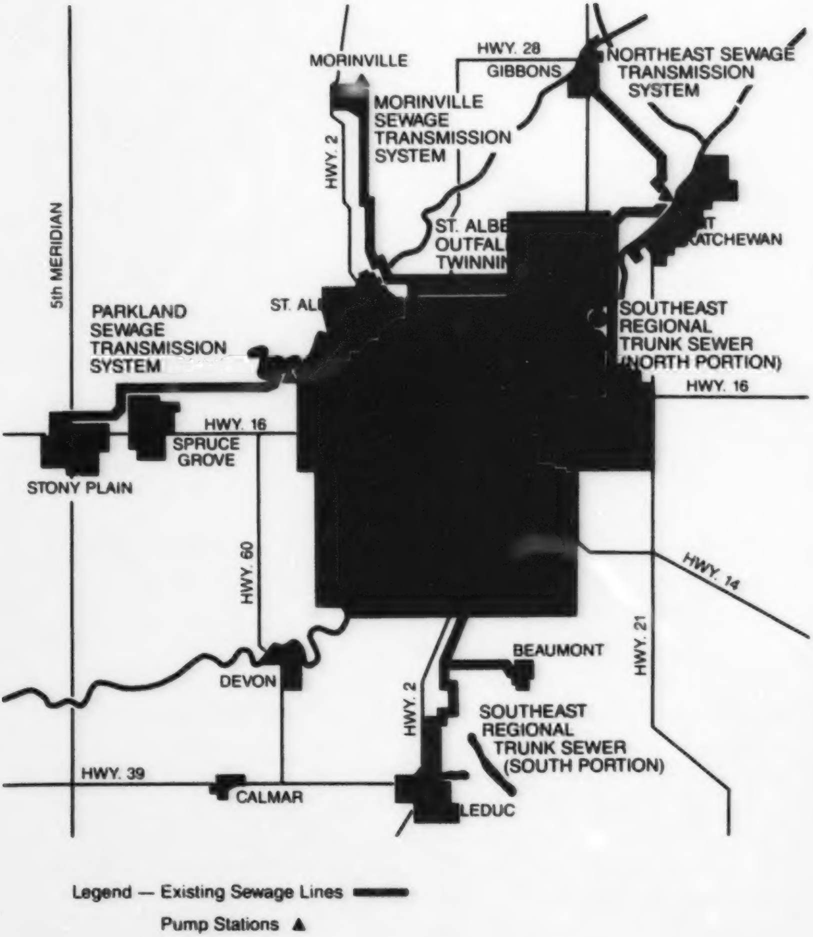
MORINVILLE
HWY. 28
GIBBONS
NORTHEAST SEWAGE TRANSMISSION SYSTEM
MORINVILLE SEWAGE TRANSMISSION SYSTEM
HWY. 2
5th MERIDIAN
ST. ALBE
OUTFAL
TWINNI
ATCHEWAN
ST. AL
PARKLAND SEWAGE TRANSMISSION SYSTEM
SOUTHEAST REGIONAL TRUNK SEWER (NORTH PORTION)
HWY. 16
HWY. 16
SPRUCE GROVE
STONY PLAIN
HWY. 60
HWY. 14
HWY. 21
BEAUMONT
DEVON
HWY. 2
SOUTHEAST REGIONAL TRUNK SEWER (SOUTH PORTION)
HWY. 39
CALMAR
LEDUC
Legend — Existing Sewage Lines
Pump Stations ▲

FIGURE 1

time, there was the need for the municipalities to upgrade the requirements for both water supply and sewage treatment. Each municipality was responsible for design, construction, and the securing of a debenture for the entire cost of the project. Provincial assistance was in the form of debenture shielding. The municipality would pay a base amount on a per-capita basis and the Province would reimburse the municipality annually up to a prescribed limit over and above this initial amount. For the sewage facilities, the upper limit was based on an estimate of the cost to install a septic system for an average family, and the lower qualifier was based on the average debenture cost incurred by medium-sized municipalities. The program was to be self-sustaining. However, Alberta's programs were subsequently changed to an up-front grant rather than an annual Provincial commitment.

In the mid-1970s, growth in the municipalities, especially in Edmonton's metropolitan area, exceeded the capacity of some systems that had been built only a few years earlier. Consequently, existing facilities had to be upgraded or new ones built. In some instances, municipalities attempted to develop a multi-municipal sewage system with the neighboring municipality. Unfortunately, local aspirations often interfered with these discussions and individual systems were built and funded by the Province.

Edmonton Regional Utility Study

Rather than continue to finance individual systems, the Province decided to assess the current and long-term water and sewage treatment requirements for the entire Edmonton region. The Edmonton Regional Utility Study evaluated the water and sewage servicing options to service the growth in the region until the year 2001. It was initiated on the premise that financial and environmental savings could be obtained by utilizing facilities common to more than one municipality. The study confirmed that, based on strict economics, the assumption was valid. The report also noted that environmental or municipal political considerations outweighed some of the apparent economic advantages.

The study included all municipalities in the metropolitan commuter shed, i.e., those communities within a 40-mile radius of the City of Edmonton. The study was divided into six major components: land use, ground water, surface water, water supply, sewage treatment and disposal, and organization and management. Through consultants, the location and size of the various land uses was predicted and population projections were made for each municipality. The availability and quality of ground and surface water for supply was assessed, and various water and sewage servicing options and levels of treatment were also evaluated. The servicing options ranged from independent systems to fully integrated regional systems. At the same time, a review was undertaken of the various organizational and legal arrangements that existed in the Province, other parts of Canada, and in some overseas jurisdictions. Although the Edmonton Regional Utility Study recommended a servicing arrangement that extensively utilized the City of Edmonton's sewage transmission and treatment facilities, local political considerations precluded it. The Province, therefore, proceeded to design and build the existing system by bypassing the City of Edmonton and providing a single treatment facility for the sewage from most of the regional communities.

Need for Cooperation

The Regional Municipal Services Act, administered by the Department of Municipal Affairs, was subsequently established as the enabling legislation for creating regional utilities. It provides for the establishment of independent commissions which can own and operate the multi-municipal systems. The legal entities established by the Minister of Municipal Affairs have a board of directors made up of one representative from each of the member municipalities served by the system.

There were a number of difficulties in implementing the regional sewage concept. One was the lack of trust that existed between the municipalities. Edmonton, by virtue of its relative size, was the dominant force in the region. Edmonton supplied water either directly or indirectly to multi-municipal user groups. The surrounding municipalities appealed to the Public Utilities Board to reduce the cost they paid for water. As a result of this appeal, they had received a substantial rebate. Secondly, the City had applied to the Province for a massive annexation which would incorporate the two next largest municipalities. The municipalities considered each other competitors in their quest for growth and development. Many did not consider a broader perspective of the benefits of regional cooperation. It may also have been the view of the municipalities that the Province was pushing something on them which they were not ready for. (In retrospect, there should have been more communication between all parties.)

The cost of the system to the municipalities was a major concern. Considerable effort was spent in determining what the ultimate user rate would be. Attempts were made to try and identify the municipalities' total existing cost of providing service. Unfortunately, various accounting arrangements and costing techniques that were utilized by the various municipalities prevented valid comparisons. At the same time, the volatile economy in Alberta was resulting in substantive capital cost increases. The municipalities wanted to know what it would cost them and their rate payers for sewage treatment. Some wanted an extra subsidy and others purposed alternate rate increases. Once the tenders for construction had been awarded provincial/municipal financing arrangements of the system were firmed up.

Each of the four regions around Edmonton had an individual who often spoke on behalf of that region. However, it was not until representatives from each of the municipalities were brought together more frequently that one of the mayors began to emerge as a leader and brought the municipalities together.

Division of Responsibilities

Unlike the individual sewage systems, the Province assumed responsibility for all aspects of design and construction for the capital region sewage system. There were many engineering difficulties that had to be resolved. Each municipality had its own internal standards and development objectives. These affected design parameters, servicing arrangements, and costs. In addition, the Province wanted to know who was going to operate the system. The City of Edmonton was the only municipality that had the technical staff to operate such a facility. A number of unsolicited inquires were received from the private sector. The Province wanted the operator to be a member of the design planning team and on site during construction. In lieu of establishing the operating agency, City of Edmonton staff were used as a technical review group.

Over time, differences between the municipalities, their employees, and the individuals on council have diminished, and the municipalities appear to be taking a broader perspective to the sewage servicing needs of the region. Although the engineering considerations were significant, interpersonal relationships and to a lesser extent financing had a much more significant impact on the ultimate configuration of the system.

FORMATION OF A TASK FORCE

To overcome the municipalities' concerns about the cost of being part of the regional system, a task force was set up by the Province. It was composed of municipal and government department representatives and led by an independent chairman. Its objective was to recommend the most feasible and equitable financial arrangement and organizational structure. It made a number of recommendations covering financial, rate setting, administrative, and technical concerns, all of which were ultimately accepted by all parties and allowed regionalization of sewage services to proceed. (The key recommendations are outlined below.)

Minimizing the Financial Impact

One major concern of the municipalities was the financial impact of both the larger capital investment and increased operating cost of the regional transmission and treatment system on individual householders. Capital investment was high because of the large scale of the system, the large capacity for future growth built into it, and the higher level of treatment technology being used. As well, existing facilities, although generally overloaded and in need of upgrading, became redundant but were still being paid for.

The municipalities' objective was to keep sewage utility rates at a level acceptable to their citizens and competitive for development, which meant keeping them comparable to rates in the City of Edmonton. To achieve this, it was essential that the Province make a major financial contribution to the system under its sewer grant program. The Province agreed to the following:

- assumption of 90 percent of the system's capital cost, requiring the Commission to assume only the remaining 10 percent by way of debenture debt;
- deferring payment to the Province of this 10-percent capital cost share during construction and the first 3 years of system operation;
- retiring the existing debt on all redundant local facilities;
- acquiring the portions of local facilities needed for regional use and transferring them to the region at no cost; and
- paying system operating cost in the year prior to the Commission's formally acquiring the system from the Province.

Administrative Structure

Another concern was equity among members both in terms of rates and of representation. A single Board, rather than several, was recommended.

This made rates uniform across the region and not subject to the differences in capital and operating cost between various branches of the system due to distance and pumping requirements. A one-member/one-vote system of board representation and voting was adopted, again to maintain equity between members despite the large variation in system usage. (The connected population of members ranges from 1000 to 38,000).

The member municipalities also wanted the role and responsibility of the Commission in providing for growth and increase in demand to be defined. To preserve local independence in making growth and development decisions, the Commission's mandate was limited to providing a wholesale sewage transmission and treatment service to its members. Local collections systems were not included in the regional system. The Commission must provide service on an as-required basis and not direct or restrict development. It was also agreed that offsite levies would not be used to finance development and reduce rates. To give the Commission the necessary independence from the municipalities, all regional facilities within municipal boundaries are owned by the Commission and arrangements were made to transfer existing municipal facilities performing a regional function to the Commission.

The task force was able to resolve the regional municipalities' financial and organizational concerns and so gain their support for the regionalized wastewater system. The Province's commitment to a high level of grant funding for the capital cost of the system was a key factor. The task force also was the forum through which the municipalities established their relationship as a regional group and the leadership of the future Commission emerged. The Commission was subsequently formed by a regulation under the Regional Municipal Utilities Act which explicitly included the organizational concepts recommended by the task force.

FINANCIAL STRUCTURE

As noted previously a major capital grant was the key element in the Commission's financial and rate structure. Several other major finance-related recommendations were made by the task force and adopted by the Commission. The regional system is required to operate on a break-even basis, with rates adequate to recover both operating and capital costs (the 10-percent share debenture financed by the Commission). The rate must also be uniform across the region to maintain equity between the members despite the differences in cost between various system branches.

Determining the Rates

Because of the cost and inherent difficulties in accurately and reliably metering sewage flows, it was agreed that rates would be based on wholesale water consumption for each member. In this case, water consumption is being used as a method of fairly allocating system costs rather than a surrogate measure of sewage flow. Water consumption and sewage flow are usually close to being equal, and this method of charging for service is generally accepted as being fair and cost-effective.

To maintain greater stability in rates and rate increases, the Commission has accepted a rate stabilization plan. Operating and capital costs over a 5-year period are estimated and a uniform series of rate increases established to recover costs over this period. This was particularly useful in phasing in the debenture repayments which begin in 1990 after the initial 3-year deferral. Rates were higher than required for break-even in the initial years but lower in subsequent years until the stabilization funds are used up.

Financial Reporting

The Regional Municipal Services Act requires the Commission to submit a full financial report to both the Province's Municipal Affairs Department and its members. The Commission reports its assets at their full value less depreciation. However, depreciation is charged to a capital cost allowance account rather than considered an expense. Principle and interest payments on debenture debt are included in the operating cost to reflect the capital cost of the system.

To maintain its financial stability, the Commission maintains a minimum working capital level of 5 percent of revenue. This allows it to absorb unusual variations in revenue or expenses due to such factors as reduced water consumption in a high rainfall year or unbudgeted repair cost to a major piece of equipment. A capital reserve has also been established. An amount equal to depreciation of short-lived assets, such as computer equipment, vehicles, and office equipment, is charged to operating expenses and placed in the capital reserve. This allows for the replacement of assets with useful life-spans significantly shorter than the debenture terms of 15 years.

ADMINISTRATION

The Commission is administered by a Board consisting of one council member from each municipality. The Board elects a chairman and vice-chairman from among its members. The Board sets policy, approves the budget, and generally oversees the operation of the regional sewage system. The general manager reports to the Board and is responsible for the administrative, financial, and technical functions of the Commission.

The Regional Municipal Services Act makes the Commission a corporation and gives it a broad range of powers, including hiring staff, owning and expropriating property, operating facilities, borrowing money, issuing debentures, investing funds, entering contracts with governments or private concerns, and charging for its services. It has a somewhat greater freedom of action than its member municipalities because it is not subject to the requirements of the Municipal Government Act or Municipal Finance Act. Nevertheless, the Commission tends to follow the financial and administrative practices of municipalities. For example, at present, financial services, including accounting, banking and investment, are provided by one of the larger members and therefore follows their system.

Operation

The most significant feature of the Commission's operation is its use of contracted services. Operation of the treatment plant and the pump stations is contracted out to a private engineering firm. They provide all plant operators, maintenance and supervisory staff as well as related administration and purchasing of required goods and services. Another firm is contracted to inspect and maintain the gravity sewer and forcemains and to repair them as required. Sludge from the plant is disposed of by lagooning and spreading on farmland through a contract with the City of Edmonton. Also, as previously noted, financial services are provided for a fee by one of the members.

The treatment plant is presently operating at 45 ML/d, which is half of its design capacity, and effluent quality is well within its licensed limits. Pollutant loadings have been reduced compared to those from the lagoon systems which have since been eliminated. As well, treated effluent is now discharged directly to the North Saskatchewan River rather than to small tributary creeks and streams. This has improved their water quality.

FUTURE ISSUES

The regional system has solved the problem of inadequate local treatment facilities. However, it has accentuated the problem of excessive stormwater inflow and infiltration into local sanitary sewers. Lagoon systems, with their relatively large volume and long detention times, were not seriously affected by short-term flow peaks. The peak flow capacity of the plant is much more limited and the impact of high flows more serious. Peaks during rainstorms have been up to six times the average dry-weather flows and have exceeded the hydraulic design capacity of the plant. As a result, primary effluent and, at times, even some of the influent are bypassed.

This problem is the result of infrastructure deficiencies in the local collection systems. An ongoing program of reducing stormwater inflow and infiltration along with possible in- or off-line storage of excess flows will have to be adopted to avoid increasing bypasses or having to expand plant capacity prematurely. Also, some uniformity in servicing standards and peak flow allowance will have to be adopted to maintain equity among the members.

Another issue will be the setting of standards for influent sewage quality. As yet no standard has been adopted because the sewage is almost entirely from domestic sources. However, as industrial discharges increase, it will be necessary to adopt such standards and a mechanism for their enforcement to ensure that the plant effluent and sludges can meet a high environmental standard.

Although it is clear that the Commission must expand and improve the existing plant and transmission system as demand increases, the responsibility for building major new trunk sewer connections has not been determined. If built by the Commission, the cost of a line benefitting only one or a few members would be shared by all members. This will pose a major challenge to the regional concept.

SUMMARY

From this experience with regional wastewater treatment, it appears that regionalizing on this scale will not occur spontaneously. The high capital cost cannot reasonably be recovered from the initial population base and the municipalities involved naturally tend to focus on their own interests rather than those of the region. Overcoming these obstacles requires commitment and leadership from the provincial level of government as well as a substantial financial contribution. Strong leadership is also needed at the municipal level to encourage development from a regional perspective.

Implementation of the Capital Region Sewage Commission has ultimately been successful and a stable organization and operation has been achieved. The system has resulted in a number of benefits, including: elimination of less efficient treatment systems with capacity often inadequate for current needs, higher treatment standards and improved water quality in local creeks and streams, and an installed capacity adequate for many years of future development. The cost of the system to the public being served has been accepted and, in fact, has been lower than originally estimated.

The municipalities involved have developed a regional perspective on wastewater treatment. It remains to be seen whether this will continue to develop and strengthen. If it does, it is possible that greater regionalization of water distribution and development of regional stormwater or solid waste systems may occur.

CHALLENGES FACING SMALLER MUNICIPALITIES

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ABSTRACT

Small towns are caught in an enormous dilemma. To avoid raising property taxes, funds that should have been spent on maintaining the infrastructure were instead spent on recreational amenities in answer to the wishes of the inhabitants. Now, because the infrastructure is in shambles, small towns cannot expand. Yet expansion is the key to their continued existence.

RÉSUMÉ

Les petites municipalités se retrouvent devant un dilemme de taille. Pour éviter de hausser les taxes foncières, les fonds qu'elles auraient dû consacrer à l'entretien des infrastructures ont été plutôt destinés aux installations récréatives, répondant ainsi au désir de leurs habitants. En raison même du piètre état de leurs infrastructures, ces muncipalités ne peuvent tout simplement pas s'étendre. Pourtant, l'expansion est essentielle à leur survie.

VALUE OF SMALLER URBAN CENTRES

In Manitoba, more than 60 percent of the population is centred in the City of Winnipeg. This is not a healthy situation for the province and limits the options for our youth. If the trend of migration away from farms is to be slowed down or discouraged, smaller urban centres will have to be supported, so that they can provide employment opportunities to those who required off-farm income to supplement farm income. Not everyone wants to reside in a major city. Unless employment opportunities exist or are created in small towns, people will be forced to migrate to larger cities to provide for their families. Small towns provide an alternative life-style, a quieter way of life.

PRESENT STATUS OF SMALL TOWNS

During the 1950s and early 1960s, a number of small towns and villages responded to ratepayers' demands and commenced installation of sewer collections and disposal systems, water supply, treatment and distribution systems hard-surfaced streets, complete with curbs, gutters, and sidewalks. These were the basic services required to provide the essential needs of the day. They were priority items, hence the necessary appropriation of funds to supply these services, which we now call infrastructure.

The late 1960s and 1970s created quite a different demand on services. More leisure time resulted in the demand for recreational and cultural opportunities. Society in general became much more mobile: people worked in a large centre and resided in small centres. Hence, they demanded that services similar to those provided by major cities be provided in the small centres. To entice people to remain in or relocate to small towns, councils had to provide recreational centres, skating rinks, swimming pools, benches, parks, museums, libraries - services which the public feels is their right to have and to use.

To keep the tax structure competitive and in line, funds which perhaps should have been used or set aside in a reserve to refurbish infrastructure were then used to construct recreational and cultural services. It was not possible to do both and still remain competitive. The result is why we are here today. Vast sums of money are now needed to restore the infrastructure, the basic service required to keep small towns alive.

CONTRIBUTING FACTORS TO OUR PLIGHT

The circumstance with which smaller communities are faced does not rest entirely with the local politicians. We may have to assume our fair share of the blame; however, the problem must also be addressed by the senior levels of government

1. Federal/provincial programs provided assistance to hamlets and rural areas by contributing substantial amounts of money for water services. Programs funded by the Department of Agriculture often helped those who were not in the farming sector with pumping and treatment facilities, distribution system, and private connections to the distribution system.

Urban centres had to qualify for assistance by having the required debt load: 20 mills in water services were required before small towns received any provincial assistance; 8 mills for sewer and 12 mills for water.

2. Cities have access to a number of federal/provincial programs not available to small towns; for example, subsidized rent to enable new development opportunities to establish and grow.
3. Major cities have direct lobbying powers with provincial governments; small towns do not have this direct access to senior levels of government.
4. In Manitoba, we are aware of only three towns that did not receive any provincial assistance for their water works or sewage treatment facilities. Morden happens to be one of these towns.

SOLUTIONS TO OUR PROBLEMS

The future may look bleak, but it is far from hopeless. Several towns in Manitoba have done remarkably well in recent years.

1. The Town of Altona has a dynamic industry in O. W. Friesen & Sons Ltd. The firm, founded by local investors, is widely recognized for its excellent printing, and employs 300 persons on a full-time basis and another 100 on a part-time basis.
2. The Town of Morden attracted the Tupperware Company in the late 1970s. The Morden Plant enjoyed a recent expansion, and now employs more than 300 persons.
3. The Town of Winkler enjoys local entrepreneurship, one of which is the Triple E Company, well known throughout the nation; it employs in excess of 300 people.
4. The Town of Steinbach may have one of the larger industries in rural Manitoba. C.T. Loewen & Sons (Loewen Windows) employs 580 people in the Steinbach operation alone.

The attitude of the citizens, helped by progressive-minded councils, creates an environment in which developers, employers, and their dedicated employees feel comfortable. A town represents an alternative to big cities.

The progressive, small towns need not suffer the fate of so many other small urban centres. The basic essential services, however, have to be restored. Failing this, even the progressive towns will cease to exist.

We have no choice but to reprioritize our expenditures and come up with the funds needed to restore our infrastructure. We cannot, however, go it alone. We need help from the provincial and federal governments. Town of Morden correspondence requesting tripartite funding goes back to 1981, and has continued unabated to the present. Success has been slow in coming. For example, the $3 million expenditure facing the Town of Morden to upgrade the present sewer system will result in an increase of 18.5 mills. This equates to $166.50 for a house assessed at $9,000.00: Allied Farm King would pay $4,799.46; a service station would pay $301.18.

THE FUTURE

When we receive the desired assistance from the federal and provincial governments, we will be able to fund the necessary restoration of our deteriorated infrastructure. Councils will have to be committed to this program, and communicate it very clearly to the public. The ratepayer will have to understand the situation. Understanding, commitment, and perhaps some political sacrifices may be necessary, if our small towns and villages are to be saved. We have no choice in this matter. Social services appear to be essential today, but if we have insufficient funds for both infrastructure and the desired social services, then councils will have to draw a line somewhere. Towns without water, sewer, paved streets, bridges, etc. will not survive.

SUMMARY

Assuming that we can solve the deteriorating infrastructure and that we succeed in obtaining the desired funding from senior levels of government - then what? Resolving this major problem merely brings us to the next obstacle: expansion of the existing essential infrastructure.

In Morden we have been served with an order from the provincial government that no further expansion is allowed until our sewage treatment facilities have been upgraded. Other towns in Manitoba are facing the same dilemma. In Morden's case, an immediate expenditure of $3 million is needed this year.

To sustain our growth, we need development and expansion. By succeeding in development and expansion, our infrastructure is now operating at, or beyond, capacity. The very development and expansion that municipalities compete for creates a demand for expanded infrastructure, costing in most instances - depending on the relative size of the municipality - millions of dollars. "Catch 22", wouldn't you say?

We have now come full-circle. We cannot expand until our deteriorated infrastructure is brought up to current standards. Municipalities simply cannot afford to bring the infrastructure to its proper state of repair and, at the same time, expand existing systems operating at optimum capacity - and still maintain a reasonable tax structure.

THE ROLE OF COMPUTER-MODELLING IN URBAN INFRASTRUCTURE REHABILITATION

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ABSTRACT

With the advent of the personal computer (PC), the first activity many municipal engineers carried out was to convert hydraulic systems analysis programs to run on a PC. With the recent increase in the PC's computing power, more data-intensive procedures have been devised to deal with infrastructure rehabilitation. Early efforts in infrastructure rehabilitation assessments have focused mostly on inventory and physical attributes. To be more cost-effective, the development of infrastructure rehabilitation programs should now combine the hydraulic assessment of municipal system capacities with the results of inventory assessment, future loading conditions, and interaction with the other utilities.

This paper outlines an approach which can be used to incorporate computer-modelling in infrastructure rehabilitation assessment. It outlines pitfalls that may be encountered in conducting infrastructure rehabilitation studies and how to integrate the evaluations of water distribution systems, sanitary sewer systems, and stormwater management systems into the development of rehabilitation schemes. Examples of the application of these procedures, which have been applied in both western and eastern Canada, have been included.

RÉSUMÉ

L'avènement de l'ordinateur personnel a poussé de nombreux ingénieurs municipaux à adapter les programmes d'analyse des réseaux hydrauliques à l'informatique. L'accroissement, ces derniers temps, de la puissance des ordinateurs personnels a permis de mettre au point des méthodes d'exploitation poussée des données concernant la réfection des infrastructures. Les premières tentatives en ce sens ont surtout porté sur l'état des immobilisations et leurs caractéristiques physiques. Pour se révéler encore plus efficiente, la création de programmes de réfection des infrastructures devra dorénavant concilier l'évaluation de la capacité des réseaux hydrauliques municipaux et les résultats de leur état, de leur charge ultérieure et de leur interaction avec les autres services d'utilité publique.

L'exposé met en relief une méthode permettant d'intégrer la modélisation informatique à l'évaluation des travaux de réfection des infrastructures. Il souligne les pièges que l'on risque de rencontrer en effectuant des études de réfection des infrastructures, et les moyens d'inclure l'évaluation des réseaux d'alimentation en eau, d'égouts séparatifs et d'égouts pluviaux dans l'élaboration de projets de réfection. Y sont illustrés des exemples de mise en oeuvre de ces procédés déjà tentés dans l'est et dans l'ouest du Canada.

INTRODUCTION

Historical Overview

The advent of IBM's personal computer (PC) in 1981 marked the beginning of an exodus of municipal engineering software from the mainframe computer (see Figure 1). The PC could handle the simple Hardy Cross and the complex, but more efficient, Newton Raphson and Linear Theory water distribution system analysis programs. With a dedicated PC machine, the turn-around time for this type of analysis was at least as good as that of mainframe computers. The analysis of sanitary sewer systems was easily handled by the PC because of the user-friendly computer environment and the simpler nature of steady-state sewer hydraulics. Drainage design by the rational method was equally well facilitated; however, detailed hydrograph analysis of programs, such as

SWMM and ILLUDAS, required a few more years before the combination of faster clock-speed, larger memory capacity, and improved compiler capability finally allowed these programs to operate effectively on a PC.

The advent of the PC did more than just facilitate hydraulic analysis for municipal engineers. It opened the area of information management to them. With programs, such as LOTUS 1-2-3 and dBase II, municipal systems analysis could be data-intensive - there are large numbers of pipes, manholes, pump stations and other facilities in these systems. With information management programs, the ability to process the data for these systems was such that the need to 'skeletonize', i.e., deal with only the large or important pipes, was reduced. The entire system could now be analyzed in great detail without great additional costs due to data preparation, input, and checking.

The first use of the PC for database management was to assemble and reformat data for input to the hydraulic programs. With the recent increase in microcomputer capabilities, more data-intensive procedures began to be devised to inventory the components of the municipal utilities independent of the hydraulic analyses. This system analysis approach focused mostly on the inventory of the physical attributes, maintenance activities, and physical condition of the system, e.g., Sewer Inventory and Management System (SIMS) developed in Ontario.

Currently, neither the hydraulic analysis nor the inventory procedure alone should be considered a sufficient means for developing a rehabilitation program in municipal systems experiencing both growth in new areas and deterioration in existing areas. To be more cost-effective, the development of infrastructure rehabilitation programs should now deal simultaneously with both the hydraulic performance and the inventory data. Consideration of the municipal system capacities, in conjunction with planned future expansions, and the interaction with other utilities must also be factored into the analysis.

Why and When

Some have asked "why computer-modelling?" Quite simply, computer-modelling allows the engineer to design or estimate system component sizes and capacities more precisely. Physical tests are necessary to determine how the existing system performs and to calibrate an appropriate computer model. However, once calibrated, the computer model can provide information about the existing system more efficiently and is the only feasible means to consider future conditions. Computer-modelling can provide the

EVOLUTION OF URBAN INFRASTRUCTURE ASSESSMENT

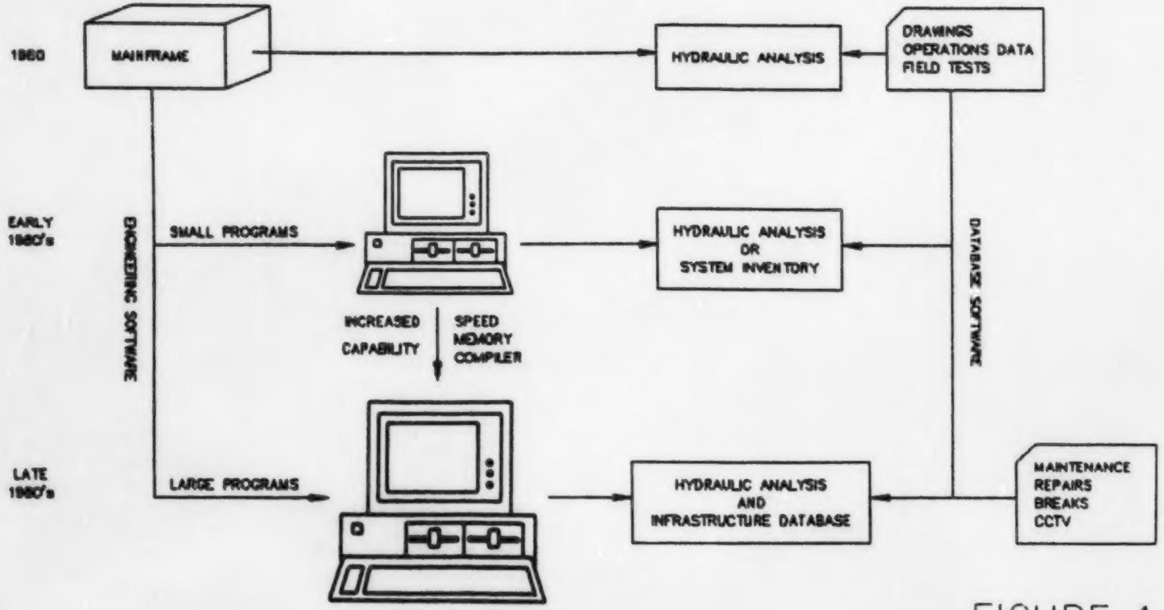
1980
MAINFRAME
HYDRAULIC ANALYSIS
DRAWINGS
OPERATIONS DATA
FIELD TESTS
EARLY
1980's
ENGINEERING SOFTWARE
SMALL PROGRAMS
HYDRAULIC ANALYSIS
OR
SYSTEM INVENTORY
DATABASE SOFTWARE
INCREASED
CAPABILITY
SPEED
MEMORY
COMPILER
LATE
1980's
LARGE PROGRAMS
HYDRAULIC ANALYSIS
AND
INFRASTRUCTURE DATABASE
MAINTENANCE
REPAIRS
BREAKS
CCTV

FIGURE 1

comprehensive systems analyses in a relatively short time. These traits make computer-modelling cost-effective and therefore highly desirable.

Computer-modelling is necessary in urban infrastructure rehabilitation because hydraulic capacity, not just age and physical condition, has an impact on rehabilitation alternatives. Hydraulic inadequacies can form the basis of rehabilitation measures where no structural inadequacies exist. Only complete hydraulic and structural analyses can allow the determination of all possible system inadequacies which may require rehabilitative measures.

An urban infrastructure assessment should not be limited to just public health utilities, e.g., the water distribution and the sanitary sewer systems. All utilities under a municipality's jurisdiction, e.g., water, stormwater management, sanitary sewer, sidewalks and roads, should be evaluated simultaneously and integrated in the development of a rehabilitation program in order to provide cost optimization.

Rehabilitation, which often involves excavation in built-up areas, usually costs much more than pipe placement in new developments. As a result, it is desirable to minimize street excavation, completing all possible utility replacements at the same time. A single, total rehabilitation effort within a street is more cost-effective and makes for less public disruption than several individual efforts.

DATABASE

The results of several separate utility analyses must be combined within an urban infrastructure assessment. Therefore, a common database, which includes a global network of common links and nodes, must be established. Each individual utility assessment must be made within this global link and node network (although a local link and node system is often also used to maintain the manhole numbering schemes in sewage and drainage systems and to provide acceptable identification numbers to various systems analysis computer programs). This will facilitate a logical connection between the individual assessments. Once combined, the resulting overall infrastructure rating can provide an identification of overall system weaknesses which can be used to develop a rehabilitation program.

The data that are collected must be relevant to the project and be required in some part of the system analyses. Too often, irrelevant data or data only remotely related to the assessment are collected and inputted into the database. The data relevant to an urban infrastructure assessment can be considered under five different categories:

- physical description and connectivity
- loading information
- physical condition
- maintenance and repair information and
- hydraulic performance

Computer-modelling, using data from the first four categories, is required prior to determining the hydraulic performance of the system components.

Information beyond the immediate study area is also often required. Water distribution system analysis usually involves the need to model the overall system in order to evaluate the local system properly. 'Skeletonizing' the system outside the study area is often successfully used to model these facilities. Similarly, the external contributing areas for sanitary sewage or stormwater management systems must be considered. The form by which these areas are to be characterized must be determined on the basis of the requirements of the computer model used in the hydraulic analysis.

Consideration may also have to be given to the collection of data for the evaluation of possible future expansion or improvement areas. Inclusion of these considerations requires both communication with the municipality's planning department and the existence of a municipal plan.

WATER DISTRIBUTION SYSTEM MODELLING

Information required for water distribution system modelling includes:

- reservoir locations, elevations and operating ranges for water levels;
- source nodes (e.g. groundwater wells, treatment plant reservoirs or wet wells), supply rates, pump types, capacities, controls and operation;
- pressure-reducing valve locations and pressure zone boundaries; and

- pipe sizes, lengths, age, material types, etc.

A critical part of water distribution system modelling involves the calibration of the computer model. Model calibration requires adjusting source node hydraulic gradelines, system demands, and pipe roughness (e.g., Hazen William's 'C') values. The model should be calibrated to field tests which measure pipe roughness and available fire flow. 'C'-value testing should be performed at several locations throughout the study area, on various pipe sizes, ages, and material types. System 'C'-values can then be determined by augmenting textbook age-dependent values from a textbook with the test results. The model can then be further calibrated with available fire flow test results. These field tests should measure the available fire flow at several locations within different parts of the distribution system.

Once calibrated, the computer model can be used to generate a number of hydraulic conditions. The first is to develop an available fire flow rating for every pipe in the system. This is accomplished by conducting fire flow simulations at each junction in the system. The link is then rated for its fire flow capacity relative to the requirements of the Insurer's Advisory Organization (FUS, 1981). This comparison is necessary because fire flow requirements are a function of the adjacent land use and not the pipe diameter. Other criteria include available service pressure and the slope of the hydraulic gradeline. These are usually evaluated for the maximum system loading, e.g., the peak-hour demand condition.

A structural analysis should also be made by correlating pipe break data to age, year of installation, material type, etc. After such a structural analysis has been performed, the water distribution piping can then be rated for available fire flow, available service pressure, hydraulic gradeline slope, age, break frequency, material type, and strategic importance.

SANITARY SEWER SYSTEM MODELLING

As with the water distribution system modelling, it is important to calibrate a sanitary sewer system model. The model must not only be calibrated to flows from sanitary (human activity) sources, but also to extraneous flows comprised of inflow and infiltration (I/I). Care should be taken to gather source information accurately for the contributions to sanitary sewer flows. These include the number of residential houses, apartment units, and the contributing area of commercial, institutional, and industrial sources for each pipe.

I/I is more often a problem in sanitary sewer systems where:

- the piping is old and jointing methods do not assure water-tightness;
- combined-sewer systems still exist, resulting in high amounts of inflow during storms;
- high groundwater table elevations exist;
- there is a high incidence of breaks;
- roof leader and weeping tile systems (foundation drains) are connected (inadvertently or intentionally) without approval; and
- the design criteria and inspection of pipeline and house connection installation were not stringent.

In many systems, I/I comprises the majority of the design pipe flow. As a result, it is necessary to quantify I/I and locate its sources. For this reason, flow and precipitation monitoring, field-monitoring (e.g. smoke and dye tests), and video camera inspections are necessary to establish I/I estimates before computer-modelling can commence. Flow-monitoring at various locations throughout the sanitary sewer network, correlated to rainfall measurements and compared with closed-circuit television inspections, are vital in determining amounts and sources of I/I. The costs of these exercises are high and often determine the extent to which they are done.

The hydraulic assessment can provide information for a number of loading conditions. From these, each pipe can be rated for its capacity relative to the design flow (which would include the estimated I/I flow). Design ratios (the ratio of the design flow to the pipe's full flow capacity) provide the numerical basis for rating the capacity attribute for the pipe. Ratios of the pipeline velocity during dry-weather flow to a specified self-cleansing velocity provide the means to rate each pipe for its ability to maintain its capacity without frequent maintenance.

Factors to consider when rating the sanitary sewer system include pipeline capacity relative to design flow, pipe velocity at low (e.g., dry-weather) flows, pipe material, structural condition, break records, slope and sag problems, identified high maintenance runs, and strategic importance.

STORMWATER MANAGEMENT SYSTEM MODELLING

As with water distribution and sanitary sewer system modelling, it is important to calibrate stormwater management system models. As a result, a rainfall/runoff monitoring program should be established for a duration long enough to measure at least one significant rainfall/runoff event.

Both major (surface) and minor (sewer) drainage systems should be assessed. Some computer models will assess both systems (e.g., OTTSWM); however, explicit computer-modelling of the major system is not always necessary. If good mapping is available, the major system can be analyzed manually to determine potential ponding locations. The capability of these local low areas to safely contain the major system design event, e.g., the 1-in-100-year rainfall event must be determined.

For many stormwater management systems, it may not be necessary to carry out a detailed analysis of the minor drainage system by using such hydrograph analysis programs as SWMM and ILLUDAS. Simple computer programs using rational-method-type procedures can determine design ratio information, provided the drainage system is small and does not contain hydraulic elements, such as detention ponds and overflows, which would complicate the analysis. Such simple programs can be used in many municipalities in the prairie provinces, where surcharged storm sewers can be tolerated. These would not be as suitable in Ontario where the weeping tile systems are usually connected to the drainage system and the consequences of surcharging are more severe.

The hydraulic assessment for stormwater management systems can be based on design flow ratios much like those for a sanitary sewer system. Where more detailed computer models (such as SWMM with EXTRAN) for the hydraulic assessment are used, the degree of surcharge relative to basement elevations can be used as a rating criteria.

Factors to consider when rating the stormwater system include:

- the capacity of the major drainage system,
- the pipeline capacity relative to design flow,
- the degree of surcharge relative to basement levels,

- structural condition,
- pipe material,
- age,
- break records, and
- strategic importance.

The development of stormwater management solutions to system inefficiencies found through the computer-modelling has to be based on engineering judgment as well as an analysis of the ratings. For systems evaluated by the degree of surcharging, a capacity increase to one link could greatly decrease the surcharging in several upstream links. Also, if one only looks at the pipes and their rating to determine system improvements, stormwater management solutions, such as detention ponds, superpipes, etc., tend to be overlooked. This is one of the major concerns of carrying out infrastructure rehabilitation assessments for any of the utility systems: the impact of non-link improvements is often neglected.

THE INFRASTRUCTURE ASSESSMENT

Each link in the local network for a given utility is rated according to its performance attributes (see Figure 2). The ratings are done on a finite scale of, say, 1 to 10, with one being the best and ten being the poorest value. These ratings may be assigned on a completely objective basis, as with design ratios for pipe capacity (see Figure 3), or in a more subjective basis, as with CCTV inspection ratings (Table 1). The rating system for each of the selected attributes of the utility is first applied (see Figure 2). These ratings are then combined using a weighting system which provides a weighted rating for the utility of 1 to 10. If the rating and weighting systems are appropriately selected, the typical system should have a large number of pipes rated "adequate" or better and the remainder rated from "below adequate" to "poor".

A number of concerns should be raised about these rating systems:

- The rating value for "adequate" should be the same for each attribute evaluated.

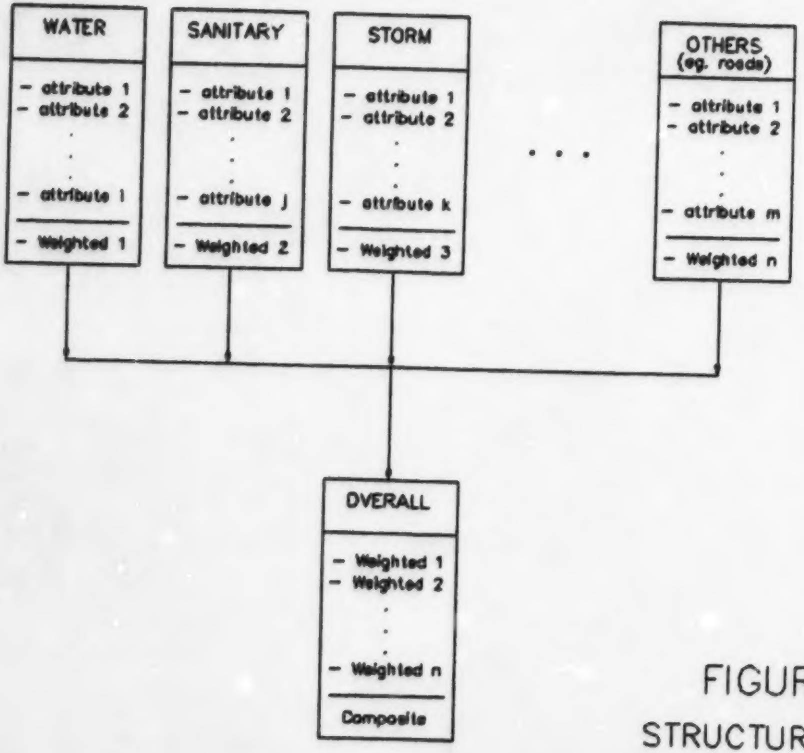
WATER
- attribute 1
- attribute 2
- attribute l
- Weighted 1
SANITARY
- attribute 1
- attribute 2
- attribute j
- Weighted 2
STORM
- attribute 1
- attribute 2
- attribute k
- Weighted 3
OTHERS
(eg. roads)
- attribute 1
- attribute 2
- attribute m
- Weighted n
OVERALL
- Weighted 1
- Weighted 2
- Weighted n
Composite

FIGURE 2
STRUCTURE OF
RATING SYSTEMS

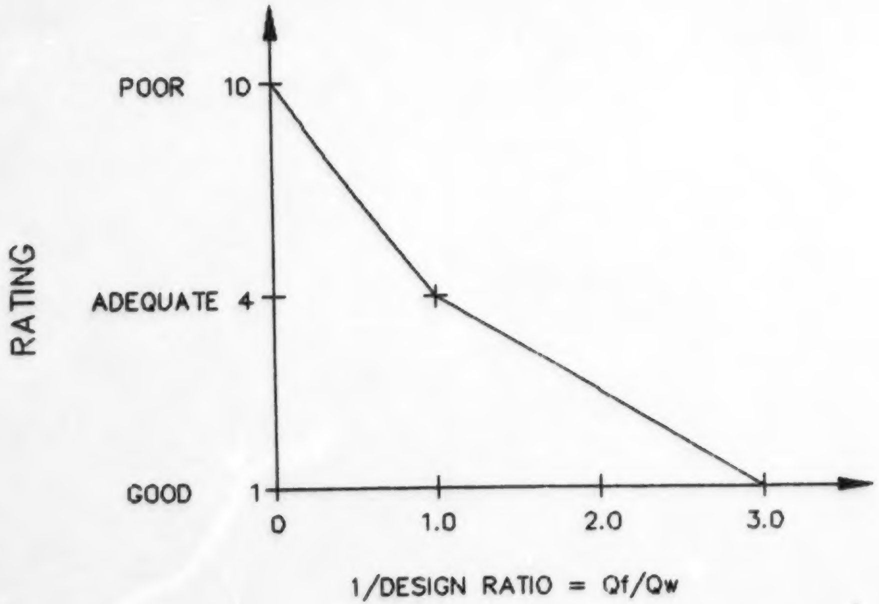

FIGURE 3

RATING SYSTEM FOR HYDRAULIC
CAPACITIES OF SANITARY SEWERS

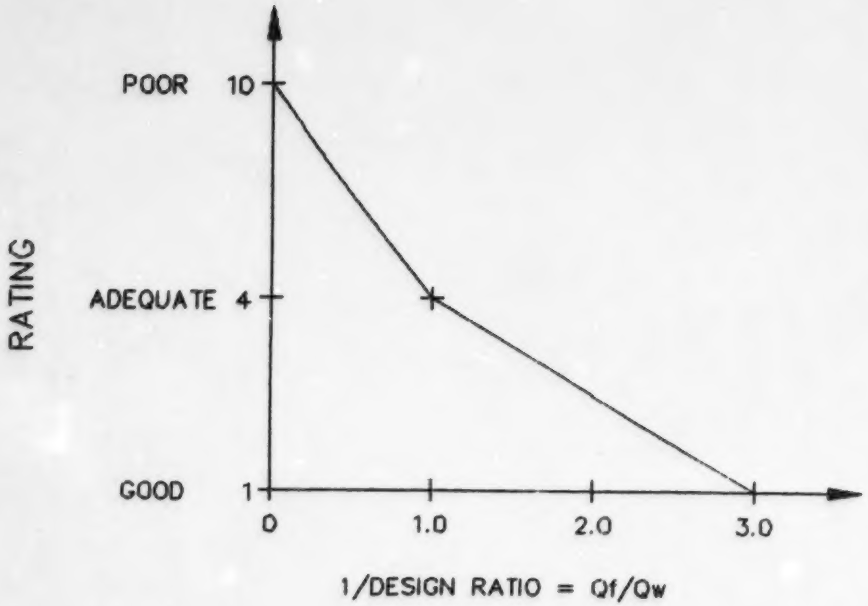

FIGURE 3

RATING SYSTEM FOR HYDRAULIC
CAPACITIES OF SANITARY SEWERS

- The causes for a poor rating of any utility must be known because replacement will not necessarily be the remedy for the shortcoming.

- It is difficult to exactly apply the rating procedure developed for one study area to another. Adjustments have been made in some studies to ensure that not all pipes are rated "poor" or "good"; comparison of the severity of problems in one system to those in another are encumbered by this.

- There is a tendency for a weighted multiple attribute rating system to dilute the significance of major problems, e.g., a broken pipe is broken and needs replacing regardless of its weighted rating.

- Rating a utility system link by link tends to focus the assessor's attention on improvements on a link basis; as well, improvements to a link downstream of a given link may change the rating (particularly for hydraulic capacity) significantly. Improvements to a non-existent link, e.g., a connection to another system, may be the most appropriate improvement.

Table 1
Rating System for Sanitary Sewer CCTV Inspections

Defect	Significance Factor
Circumferentially cracked pipe segments	1
Longitudinally cracked pipe segments	2
Deflected or fractured joints	10
Sags	3
Distorted cross-section	50
Collapsed (> 25% deformation) pipe segments	100
Open or displaced joints (dry)	5
Open or displaced joints (leaking)	5
Projecting Services	3
Deposits (roots, encrustations, debris, grease, etc.)	1

Note: The pipe run is reviewed segment by segment to accumulate the number of defects. The number of each defect multiplied by its significance factor are

> totalled to determine the number of defect points. This number is normalized to the pipe length prior to determining the weighted rating for the structural attribute.

These concerns are at the crux of the urban infrastructure assessment paradox: after all of the effort expended to quantify system attributes in these rating schemes, the engineer must still be free to use judgment and seek out alternative remedies for pipes rated "poor". To aid in this process, studies conducted by the authors have usually separated the assessment responsibilities, e.g., the hydraulic assessment is done by one engineer, the CCTV review and line break review by another, and the overall rating by a third. Frequent group meetings are held to ensure that the results are shared and that all upgrading options are examined.

After the weighted ratings have been determined for each link, the overall composite rating is determined. This is done by generating a rating for each link in the global system for each utility. This may require the combination of the rating of two or more pipes and the splitting of others as the global and local links may not coincide exactly. A weighting system must then be applied to the individual utility ratings to obtain the overall composite rating.

A number of observations can be made about the overall composite rating process:

- Little correlation between utilities rated "poor" has been found in the systems assessed by the authors.
- The tendency for the importance of poor ratings to be diluted down to "adequate" persists (if links have not shown up as "poor" on the weighted individual rating, they will not likely do so in the overall composite rating).
- As roadway costs tend to dominate the costs of the underground utilities, its weighting is high and can precipitate the replacement of some pipe, if its remaining design life is less than that of the upgraded roadway.

The overall composite rating facilitates the presentation of the results of all of the utility assessments. It allows the efficient and rational expenditure of the funds available for upgrading each utility. This is important because the sources of these funds may be diverse. It allows the planning of a rehabilitation program to minimize public disruption.

CONCLUSIONS

1. The advent of IBM's PC marked the beginning of an exodus of municipal engineering software from mainframe computers to the PC. In addition to conducting hydraulic analyses on the PC, engineers began to conduct inventories for the physical condition and maintenance activities of the municipal utilities with database management programs. Effective infrastructure rehabilitation assessment requires the integration of both the hydraulic and the system inventory assessments.

2. A **global** system of links and nodes should be established for an infrastructure rehabilitation assessment. Within this global system, each municipal utility can be analyzed and assessed by using its own **local** system of links and nodes. The overall composite rating for all utilities is determined by aggregating the individual local system ratings to the global system links.

3. Water distribution systems can have their hydraulic performance ratings determined based on available fire flows, available service pressure and hydraulic gradeline slope. These attributes should be rated relative to both existing and future system loading conditions.

4. Sanitary sewer systems can have their hydraulic performance ratings determined based on the pipeline capacity at design (e.g., wet-weather) flows and the pipeline velocity at low (e.g., dry-weather) flows. In many systems, the I/I component can comprise the majority of the design flow.

5. Stormwater management systems can have their hydraulic performance ratings determined based on the capacity of the major drainage system to deal with rare events, and the capacity of the minor (piped) drainage system to deal with more common design rainfall events. The pipe capacities can be rated based on the pipeline capacity relative to the design flows or the degree of surcharge relative to basement elevations (if connected).

6. In the application of rating systems to a given utility system, a number of concerns must be addressed:

- the rating system for each attribute should result in similar ratings for "adequate" pipes,

- the cause for a poor rating in any attribute must be noted,

- the dilution of a poor rating for a pipe in one attribute by ratings of "adequate" in other attributes must be avoided, and

- the weighting systems for each utility generally result in most pipes being rated "adequate"; some studies have adjusted the rating systems so that a reasonable number of pipes might be rated "less than adequate"; although this allows the identification of the poorer pipes, it makes comparison between study areas and longitudinal studies difficult.

7. After quantifying the hydraulic and structural attributes of a utility system with a rating system, the engineer must be free to use judgment when seeking rehabilitation alternatives for pipes rated "poor". This helps to ensure that non-pipe remedial measures, e.g., pump stations, detention ponds, etc., and non-link remedial measures, e.g., pressure zone changes, connections to other systems, etc., are considered.

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CANADIAN CONFERENCE ON MUNICIPAL INFRASTRUCTURE - WRAP-UP

Mayor George B. Cuff,
President, Federation of Canadian Municipalities

SUMMARY POINTS

1. It is my view that the problems which we have been discussing over the past 2 days with regard to the status of the municipal infrastructure will not go away. These problems affect our quality of life, our environment, and our economic future. Our ability to deal with these problems now will very much affect the quality of life which we have and which we pass on to future generations.

2. I would like to reaffirm the political commitment of the Federation of Canadian Municipalities to continuing our efforts in this regard. While there are some who would say that we should press on with other matters and put this issue aside, it is my view that this is a key issue facing all municipalities across Canada; it is one which the FCM would be ill-advised to drop.

3. I would like to call upon all municipalities, not only those represented here but right across Canada, to develop a profound and clear understanding of the status of municipal infrastructure in our own communities and communicate our concerns to our provincial and federal counterparts.

4. It is becoming increasingly apparent that we must also focus on regeneration and renewal of infrastructure in many parts of Canada. In older areas, there is far less emphasis on new development than there is on the need to renew the infrastructure which we presently have. This will require new political skills, new management systems, and will likely usher in a new political and economic era.

5. The engineering profession must also adapt to this new area. New skills will be required, engineering education must change, and new research and

development priorities must be established. In this instance, contributions from the federal government would obviously be of some assistance.

6. The whole basis of municipal finance must be re-thought. The request for property tax on which we principally rely is not the answer. User-pay systems are also not the sole answer. It is my view that we need to examine our access to other sources of revenue which have, to this day, been exclusively the prerogative of the provincial or federal governments.

7. The public demands action. It is obvious from recent media coverage that environmental protection is strongly supported. This is the number one issue in Canada today. We believe that the needs regarding municipal water and sewage systems, roads, and bridges will fall under public scrutiny and that the public will demand that we take action in these areas.

8. It is evident that our standards are changing. We now have new building codes which place stringent requirements upon us. New water-supply standards have been issued recently, so have new effluent treatment standards. As a result of all of this, our costs are increasing.

9. We must not be discouraged by the hard-line attitude taken to date by the federal government. We need to recognize that their existing policy is simply a carryover from the previous government. We now recognize that we have a new federal cabinet with new cabinet ministers. It is our hope that this new cabinet will rethink its existing priorities and agree that the infrastructure needs of municipalities must become a part of the political agenda of Ottawa

WHERE TO FROM HERE?

1. I am requesting that all participants in this conference endorse a letter from the President of the Federation of Canadian Municipalities to the Prime Minister, Deputy Prime Minister, Minister of the Environment, and our provincial premiers. This letter will outline the theme of the conference and reiterate our position.

2. Either as a part of this correspondence to the Prime Minister or as a separate piece of correspondence, we will be pressing for this issue of municipal infrastructure to be included on the next meeting of the Prime Minister and provincial premiers. It is our understanding that the date is now targeted for February 27. We have on hand a letter from Senator Lowell Murray, Minister Responsible for Provincial/Federal Relations, that an infrastructure issue will be included on that agenda.

3. We need to keep this issue in the media. As a result of that, I call upon all members gathered here to keep up the level of communication with your local and regional media.

4. We need to develop a broad base of support. I therefore ask each one of you to send letters of support to your Member of Parliament, Member of the Legislative Assembly, your Premier, and your Provincial/Municipal Association. We need to get the support of both large and small centres, urban and rural.

5. I will be asking our staff to begin planning for the next regional conference which will likely be held in the Maritimes or in Quebec. I would encourage both regions of Canada to approach us to begin work on establishing a date and location for such a conference.

6. In summing up, it is my view that, as a result of input from our provincial associations, related organizations, individuals, the media and the Federation of Canadian Municipalities, this issue will continue to be very much front and centre in the media. I believe also that we will be successful in keeping this issue on the agenda in Ottawa and in the provinces.

RESOLUTION:

Moved by Mayor Jean Maurer of Hinton, Alberta;

seconded by Mayor Tcihrob of the District of Matsqui, British Columbia

"Be it resolved that the federal government be requested to recognize that municipal infrastructure is a national issue and to therefore enter into meaningful negotiations with the other two levels of government with regard to the funding of infrastructure programs."

Resolution unanimously carried.